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Power Plant Stack Plumes in Complex Terrain: Description of an Aerometric Field Study

Geomet, Inc, Gaithersburg, MD

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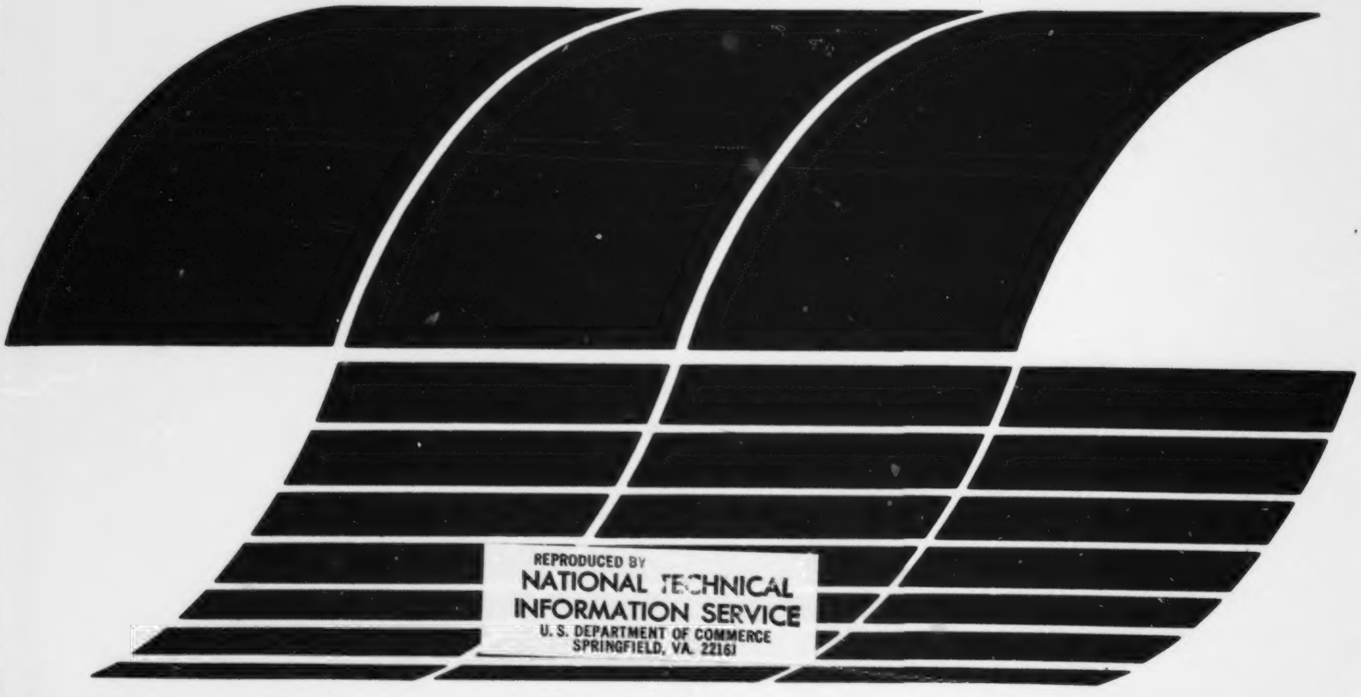
Power Plant Stack Plumes in Complex Terrain

Description of an Aerometric Field Study

Interagency Energy/Environment R&D Program Report



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16. ABSTRACT

Air quality and meteorological data collected, processed, and edited during the Clinch River Power Plant Plume Study (June 1976 through September 1977) are contained on one magnetic tape. The thirty-four files on the tape contain data of six types: (1) fixed-station data, (2) mobile ground monitoring data, (3) airborne monitoring data, (4) sulfate measurements, (5) upper-air meteorological data, and (6) plant operating data.

The fixed-station files contain hourly averages of SO_2, NO_x, NO_2 and NO along with wind and temperature data. Ground mobile files contain pollutant and meteorological data from both stationary and mobile monitoring modes. The airborne files are in the form of a series of traverses across the plume between specified check points. Sulfate measurements were taken at selected times at the fixed stations and by mobile van. The upper-air file contains pibal and T-sonde observations of vertical profiles of temperature, wind speed, and direction. Hourly emission rates of SO_2 and NO along with generator loads and stack data are contained on the plant operations file.

The order in which the files are organized on the tape, formats for each file type, and a description of the data are contained in Appendix C of the report describing the field study.

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*Terrain	*Atmospheric diffusion		08F	04B
*Field tests	*Sulfates		14B	09B
*Sulfur dioxide	*Meteorological data		07B	14C
*Plumes			21B	
*Nitrogen oxides			10B	

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Description of an Aerometric Field Study

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EPA Contract Number 68-02-2260

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ABSTRACT

A monitoring network consisting of eight fixed sites was set up and operated in the vicinity of the 712-megawatt, coal-fired, Clinch River, Virginia Steam Plant during the period of June 1, 1976 to September 30, 1977. At most of the monitoring stations sulfur dioxide, nitric oxide, total nitrogen oxides, wind direction, wind speed, temperature, and sulfates were measured. Two of the stations had 30 meter towers from which meteorological variables were measured. On four or five days per week a mobile van was operated to supplement the fixed site monitoring, and once or twice a day balloons were used to measure winds and temperatures aloft in the vicinity of the plant site. A monitor for continuous measurement of sulfur dioxide and nitric oxide was operated in one of the two plant stacks. These data were supplemented by helicopter measurements taken during ten-day periods in November 1976 and July 1977.

The system used to collect the data, the operational procedures used to run the system, and its performance record are described in this report. The data that were collected have been edited and recorded on magnetic tape and are available from the National Technical Information Service. An appendix in this report describes the formats required for reading this tape.

A report on analyses of these data will be published separately.

This report was submitted in fulfillment of Contract Number 68-02-2260 by GEOMET, Incorporated under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from June 1, 1976 to September 30, 1977, and work was completed as of October 24, 1978.

Keep as they do

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ACKNOWLEDGMENT

The assistance and cooperation of the Appalachian Power Company and the American Electric Power Company were an important contribution to this study. The company provided offices and storage and operating space throughout an 18-month period in which the field program was set up and performed. In addition, hourly measurements of the plant's operating characteristics were provided. Field personnel were granted access to all areas of the plant's operations, and plant personnel freely offered advice and data in a friendly and timely manner.

SECTION 1

INTRODUCTION

An aerometric survey was conducted in the vicinity of a power plant located in the complex terrain of the western tip of Virginia. This report describes the characteristics of the site, the equipment and monitoring operations used to perform the survey, the kinds of data obtained and available from the program, and the procedures recommended for accessing the data. The survey is the second phase of a three-phase study of the behavior of plumes from an elevated continuous source located in complex terrain. The first phase consisted of a literature review of the current state of knowledge of plume behavior in complex terrain, including both transformation and removal processes and transport and dispersion processes. The third phase will consist of an analysis of the data collected in the second phase in order to identify relationships between terrain characteristics, meteorological conditions, plant operating conditions and resulting ground-level concentrations of pollutants.

This study was undertaken because of the generally recognized shortage of real air quality measurements in mountainous complex terrain. The objective of the aerometric survey was to obtain a reliable set of measurements over a relatively long period of time on SO_2, sulfate, NO and NO_2 concentrations and on relationships among power plant emissions, meteorological variables and ground-level concentrations in areas of complex terrain.

The combustion processes of coal-fired electric power plants are major sources of sulfur oxides and nitrogen oxides. Permissible ambient concentrations for both pollutants are controlled by national ambient air quality standards, enforced under State Implementation Plans. SO_2 has long been considered a health hazard. Its emission and ambient levels have typically been used as primary indicators of power plant air pollution. More recently, the transformation of SO_2 into sulfates in the atmosphere has been studied as a probable principal agent of production of the more damaging aspects of sulfur oxide pollution. Nitric oxide and nitrogen dioxide produced in power plant combustion are of concern because the nitric oxide is rapidly oxidized to NO_2 in the atmosphere and NO_2 has adverse health effects. Nitrogen oxides play an important role in reactions leading to formation of photochemical oxidants.

The primary emphasis in the measurement program has been on SO_2, NO_x (i.e., NO and NO_2) and meteorological measurements. Sulfates and ozone were also measured, but much less frequently. There is a general belief that many hours are required for significant sulfate formation. Therefore, the opportunities to observe sulfates in the vicinity of the plant which can be attributed to the plant's emissions should be very limited. The validity of this assumption can be tested in the third phase of the study. The ozone measurements provide a limited amount of data on plume reactions, plume definition and background concentrations.

The program which evolved was constrained by the large expenses associated with a field program. The measurements made represent an attempt both to get frequent measurements of the exhaust gas plume from the plant and to observe special effects caused by the complex topography.

SECTION 2

THE CLINCH RIVER STEAM POWER PLANT

PLANT SELECTION CRITERIA

The locality selected for the field work was required to have the following characteristics: the emission source was to be a steam-electric plant with a generating capacity of 700 MW or greater and coal-fired boilers; in a nonurban, mountainous area, isolated from other sources of SO_2; some terrain relief in the surrounding region was to be more than 1.5 times the height of the stacks at the steam-electric plant. Ease of movement in the region of the plant and an adequate network of roads in the plant locality to facilitate mobile sampling and to allow flexibility in selecting fixed monitoring sites were also important considerations.

The Clinch River Steam Plant, owned by the Appalachian Power Company, is the steam plant. The installed capacity of electrical generators is 712 MW. The plant's three boilers are mostly fueled by local low-sulfur (∿0.7%) coal; however during 1977 the plant began using larger quantities of higher sulfur coal from more distant sources. The Clinch River site has ridges and valleys both near the plant and at a considerable distance from it which are readily accessible by conventional on-the-road vehicles. A scattered rural population, served by power and telephone lines, lives throughout the area. Monitoring sites for key topographic and climatological conditions were easily available. The Clinch River plant is isolated; the only other SO_2 pollution source within a 30 km range, except for a few private residences, is a coal-drying operation (Moss No. 3 Coal Preparation Plant), located 3 km northeast of the Clinch River plant, which burns a small amount of local low-sulfur coal (see Figure 1).

Another important consideration in selecting the Clinch River Steam Plant, as the site for this study was the power company's willingness to cooperate.

PLANT CHARACTERISTICS

The Clinch River Steam Plant has a generating capacity of 712 MW. The fuel, local low-sulfur coal, is burned in three boilers. Exhaust gases are emitted through two stacks, 150 ft apart, each 453 ft high. The stack diameters are 15.6 ft and 12.5 ft. The larger diameter stack serves two boilers. Table 1 shows the exit velocity and temperature of each stack for 50, 75 and 100% load as reported by the plant. The plant operates essentially as a base load plant, with a normal diurnal variability in its output load of about 200 MW (i.e., load varies from a normal daytime peak of about 650 MW down to a nighttime low of about 450 MW).

The plant is approximately square, 400 ft on a side, and 194 ft high, with the base being 1513 ft above mean sea level. The boiler water is cooled through the use of 5 mechanical-draft cooling towers. Four of the towers, serving the first 2 boiler units, measure 67 ft by 281 ft and are 61 ft high. Each tower contains 10 22-ft fans and can cool water 19° F at a rate of 55,000 gallons a min.

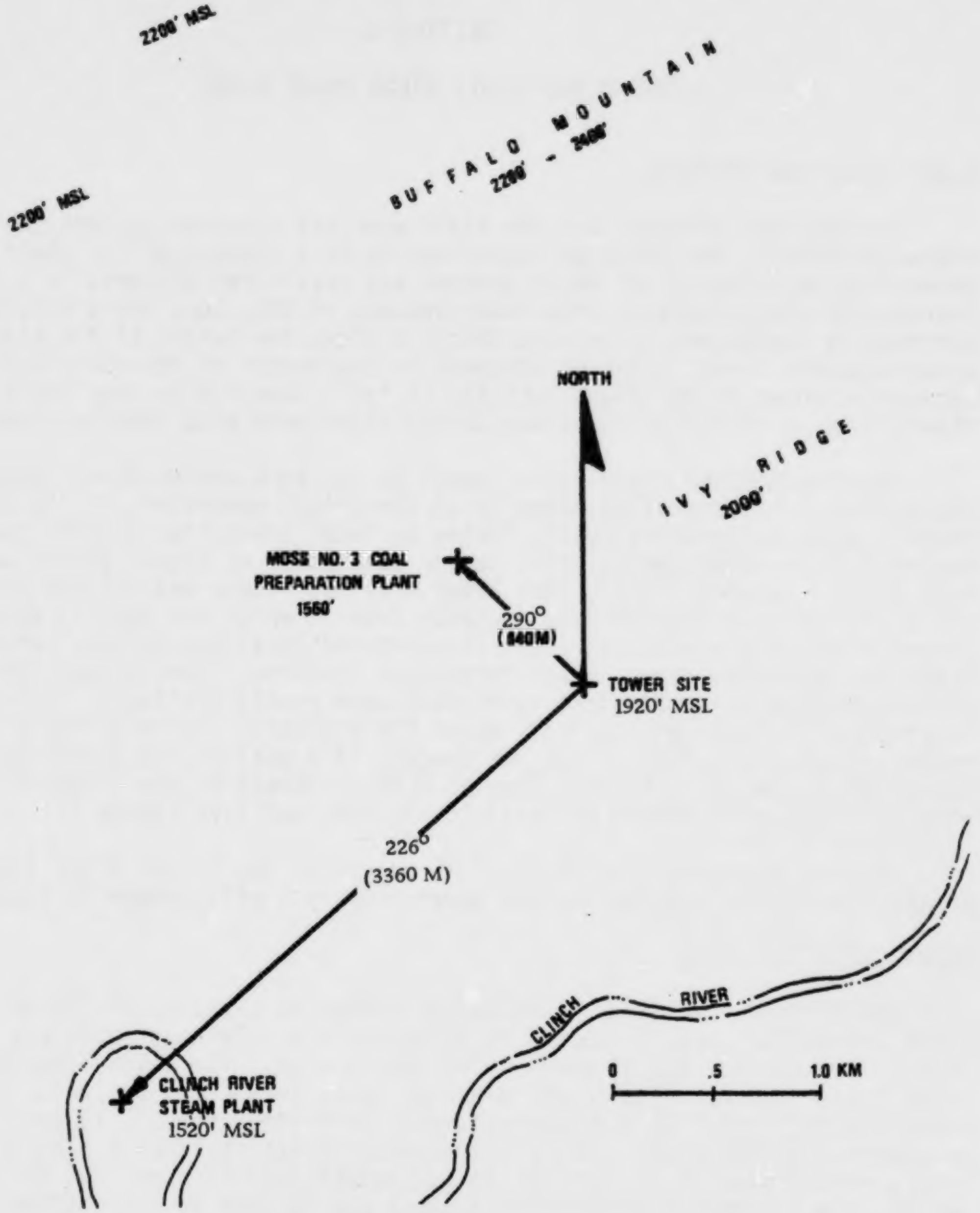

2200' MSL
2200' MSL
BUFFALO MOUNTAIN
2200' - 2400'
NORTH
IVY RIDGE
2000'
MOSS NO. 3 COAL
PREPARATION PLANT
1560'
290°
(840M)
TOWER SITE
1920' MSL
226°
(3360 M)
CLINCH RIVER
0
.5
1.0 KM
CLINCH RIVER
STEAM PLANT
1520' MSL

Figure 1. Location of Clinch River Steam Plant in relation to the Moss No. 3 Coal Preparation Plant.

The fifth tower, serving the plant's third boiler unit measures 67 ft by 391 ft and is also 61 ft high. It contains 14 24-ft fans and is capable of cooling water 20° F at a rate of 110,000 gal a min. The plant uses electrostatic precipitators with a design efficiency of 99.7% to remove flyash from the exhaust gases. The flyash that is removed is transported by truck to landfill areas near the plant. Figure 2 shows views of the plant looking north from the southside of the plant. The cooling towers are seen on the east (right hand) side of the plant.

TABLE 1. CLINCH RIVER STEAM PLANT STACK VELOCITIES AND TEMPERATURES*

	Stack #1		Stack #2	
	475 mw load capacity		237.5 mw load capacity	
Load	Velocity	Temperature	Velocity	Temperature
50%	96 fps	282 F	75 fps	282 F
75%	125 fps	294 F	97 fps	294 F
100%	131 fps	302 F	102 fps	302 F

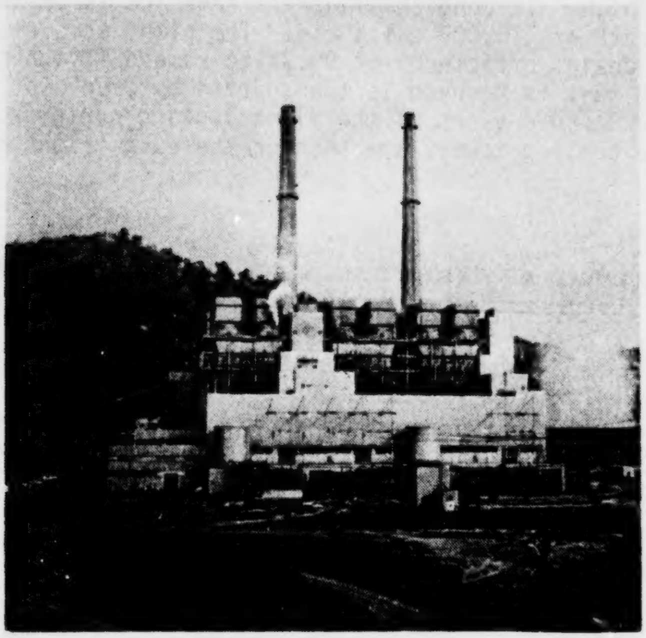
* Reported by plant engineer based on stack measurements.

The Clinch River Plant burns approximately 6,000 tons of coal a day to power its three turbine-generators. The coal is ground into a powder before it is fed into the plant's three 10-story high boilers. These boilers produce steam at 2000 lb per square in. and 1050° F to drive the turbines. The turbine-generators produce electricity at 15,000 V which is then stepped-up to 138,000 V for transmission to several substations in Virginia, West Virginia, Kentucky, and Tennessee.

TERRAIN AND CLIMATOLOGY

The site of the field measurement program was the vicinity of the Clinch River Power Plant in Carbo, Virginia that could be affected by exhaust gases from the plant. Two views of the plant site are shown in Figure 2 and the complexity of the surrounding terrain in Figure 3. The location of this plant in western Virginia is shown in Figure 4. The details of its surrounding terrain, including monitoring site locations, are shown in Figure 5.

There are ridges exceeding 1-1/2 times stack height within 3 to 5 km of the plant in all quadrants of the compass. Elevations exceeding stack height by factors of 3 or more occur within 8 km to the northwest and 14 km to the southeast. Clinch Mountain, located 14 km southeast of the plant, runs northeast-southwest for approximately 25 km and reaches elevations in excess of 4,200 ft. Big A Mountain, located 20 km northeast of the plant, is a finger-like projection

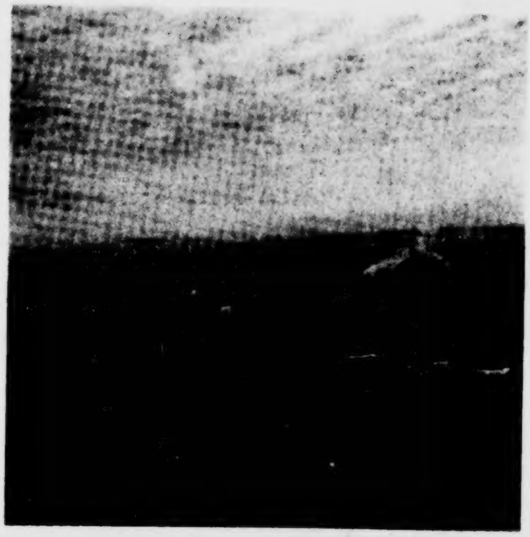


View of the Clinch River Steam Plant

View of the Clinch River Steam Plant

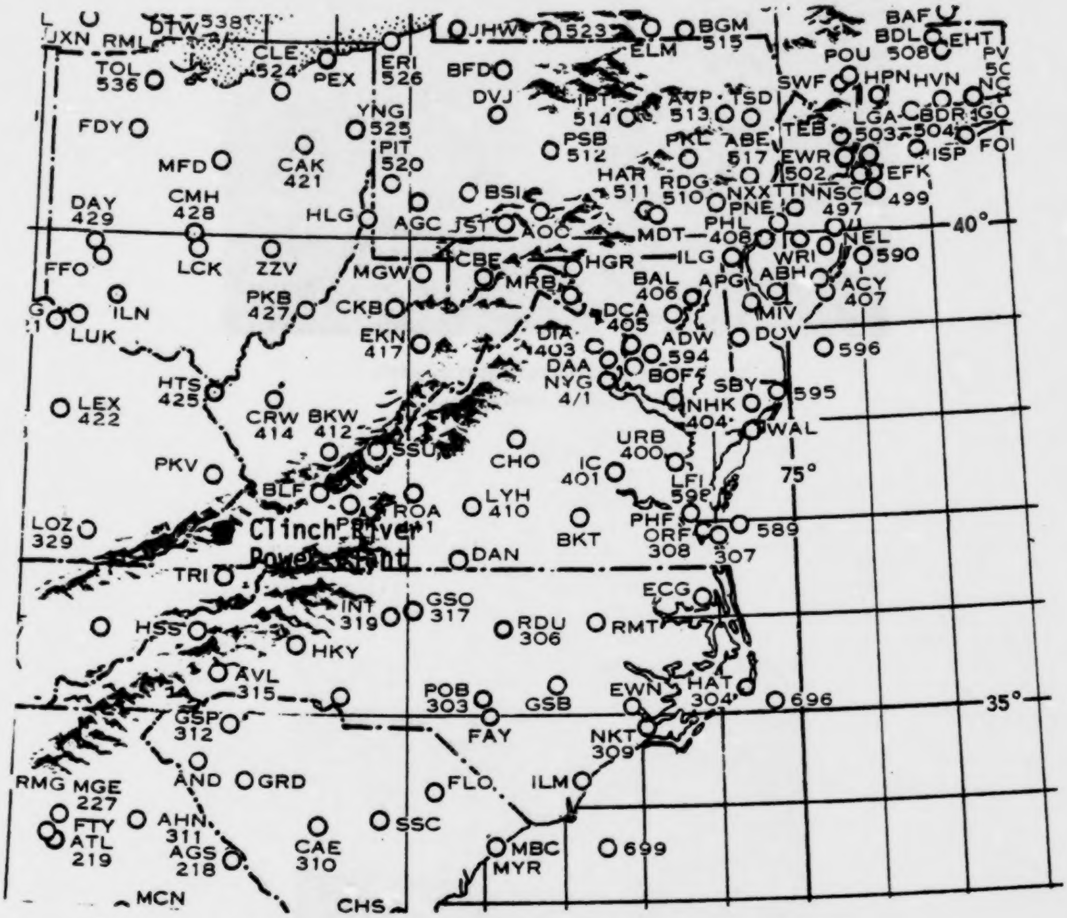
Figure 2.

View of the plant taken approximately
2 km NW looking toward the SE.



View of the plant taken approximately
7 km ESE looking toward the WNW.

Figure 3.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ELM
BGM 515
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BDL 508
EHT
TOL 536
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HPN
HVN
DVJ
IPT 514
AVP 513
TSD
YNG 525
FDY
TEB
LGA 503
BDR 504
ISP
PSB 512
PKL
ABE 517
EWR 502
EFK
MFD
CAK 421
PIT 520
HAR 511
RDG 510
NXX
TTN
NSC 497
499
DAY 429
CMH 428
HLG
AGC
BSI
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AOO
MDT
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PHL 408
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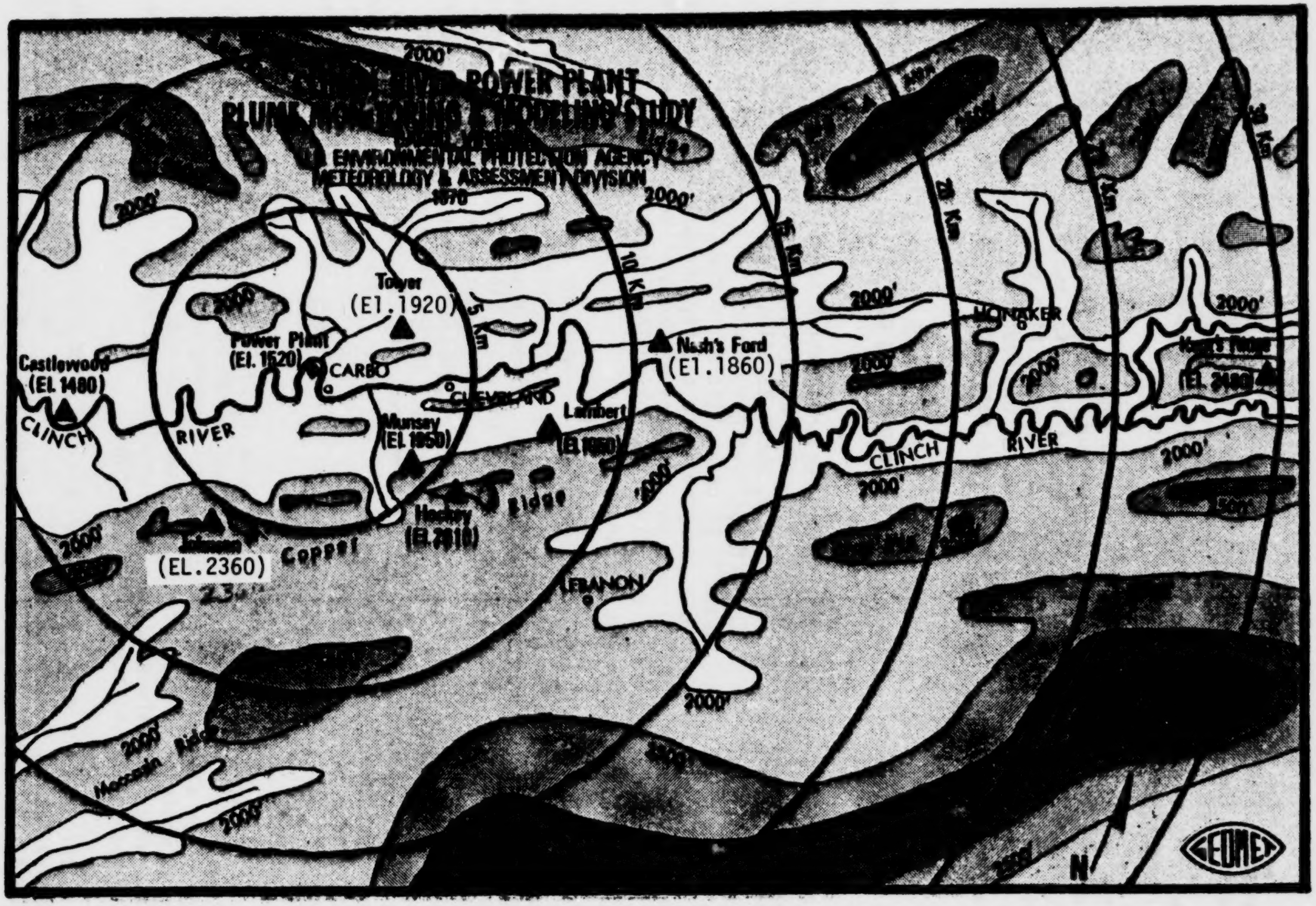
DIA 403
ADW 594
DOV
596
DAA
NYG 4/1
BOF
SBY
595
HTS 425
NHK 404
LEX 422
CRW 414
BKW 412
WAL
SSU
CHO
URB 400
PKV
IC 401
LFI 598
75°
BLF
ROA
LYH 410
LOZ 329
Clinch River Power Plant
BKT
PHF
ORF 308
589
307
DAN
TRI
ECG
INT 319
GSO 317
RDU 306
RMT
HSS
HKY
AVL 315
POB 303
GSB
EWN
HAT 304
696
35°
FAY
GSP 312
NKT 309
RMG
MGE 227
AND
GRD
FLO
ILM
FTY
ATL 219
AHN 311
AGS 218
SSC
CAE 310
MBC
MYR
699
MCN
CHS

Figure 4. Location of the Clinch River Steam Plant.



POWER PLANT
PLUME MONITORING & MODELING STUDY
ENVIRONMENTAL PROTECTION AGENCY
METEOROLOGY & ASSESSMENT DIVISION
Toyer
(E1.1920)
Power Plant
(El. 1520)
CARBO
Castlewood
(El. 1480)
CLINCH
RIVER
Munsey
(El. 1850)
CLEVELAND
Lambert
Hockey
(El. 2810)
Ridge
Johnson
(EL.2360)
Copper
Nash's Ford
(E1.1860)
LEBANON
HONAKER
CLINCH
RIVER
10 Km
15 Km
20 Km
25 Km
30 Km
2000'
Moccasin Ridge
N
GEOMET

Figure 5. Surrounding terrain, including monitoring site locations of the Clinch River Power Plant.

that reaches elevations in excess of 3,800 ft. Flat Top Ridge, situated 8 km northwest of the plant, is oriented northeast-southwest and reaches elevations up to 3,000 ft. The major pattern of ridges and valleys trending northeast-southwest is transected by many streams running northwest-southeast to form a truly complex terrain.

The small town of Cleveland (estimated population - 250) lies next to the Clinch River 4 km east-northeast of the plant. The town consists largely of private residences and churches, but it also has a few small, locally owned stores, a gas station, an elementary school, and a high school. The village of Carbo lies just outside the plant grounds to the southeast. Carbo, with a population of about 50, consists of private residences, a couple of churches, and a country store.

The land north of the Clinch River Plant is rich in low-sulfur coal. A large number of strip mines, as well as deep mining operations, dot the countryside.

Climatological influences for the region in which the plant is located are represented by the 40-year record of weather observations for the tri-city area of Bristol, Kingsport and Johnson City, about 35 miles south-southwest of the Clinch River Steam Plant. The National Weather Service Office located at the Tri-City Airport is the closest first order station to the Clinch River power plant. The climatological data recorded there are representative of the larger-scale features which affect both sites and many of the smaller-scale features as well. The data collected at the plant site during this study identifies the nature of the highly local influences.

During the summer season, meteorological conditions are mostly under the influence of weak high pressure systems. The storm track lies well to the north of the area and only occasionally do frontal systems pass by. During the winter, the prevailing storm track is to the south and east, along the Gulf Coast and up the Atlantic coast. The fall transition period is associated with a high frequency of occurrence of a stable air mass. Both clear days and very foggy days are common and precipitation is less frequent. During the spring transition season unstable air masses are common; the frequency of occurrence of dense fog is very low; cloudiness and precipitation are more frequent. The winter season is characterized by the highest frequency of cloudy conditions and precipitation. The area is most likely to be affected by well-defined cyclones and front systems during the winter and spring seasons.

The most common wind directions observed at Bristol are from the west-southwest and the northeast. This is typical of other stations in the Appalachian region also. The mean resultant surface wind is westerly in winter, becoming southwesterly in spring and summer. In the fall, the mean resultant surface wind is northwesterly. The mean wind speed varies from 2 mps in summer to 3.5 mps in late winter and early spring.

Clear days are most frequent in the fall, and cloudy days are most frequent in the winter. Late summer and early fall is the period of most frequent heavy fog (with visibility of one-quarter mile or less), while March and April are the months with least frequent heavy fog. These observations combined with the wind speed climatology suggest that atmospheric dispersion conditions are least favorable during the early fall and most favorable during the late winter.

Precipitation occurs at a minimum monthly mean of 2.2 in. in October and at a maximum monthly mean of 5.0 in. in July. Snow accumulations in excess of 1 in. or more occur a mean of 5 d per year. Thunderstorms occur on a mean of 45 d per year, mostly in the summer.

The normal diurnal temperature variation is 20 to 25° F and is fairly consistent all year round. The monthly mean temperature varies from 36° F in January to 75° F in July. The monthly mean relative humidity is 50 to 60% at midday all year round. In summer the mean 7 a.m. humidity is 92% and in winter it is 80%. The time of maximum humidity is around 7 a.m., and it lies between the summer and winter values in spring and fall. The high frequency of dense fog in the fall compared to spring is associated with the greater stability of the air in the fall more than with humidity.

The upper air observing station of Huntington, West Virginia (about 150 km to the north-northwest of the plant) is the closest point for which upper air data are available. Based on 3 years' data, Holzworth (1972) reported the seasonal and annual mean afternoon mixing heights at Huntington to be as shown in Table 2. The afternoon mixing height is lowest during the winter and highest during the spring. Holzworth's (1972) national scale analysis of mixing height data suggests that mixing heights near the Clinch River Steam Plant are very close to the Huntington values. However, the effects that the complex terrain in the vicinity of the plant will have in increasing the mixing height are not well established. When the mixing height is below or slightly above the height of the plant exhaust plumes, this characteristic has an important relationship to the plume behavior.

TABLE 2. MEAN ANNUAL AND SEASONAL MIXING HEIGHTS AT HUNTINGTON, WEST VIRGINIA (HOLZWORTH 1972).

Season	Afternoon mixing height (meters)
Winter	1079
Spring	1986
Summer	1641
Autumn	1340
Annual	1511

SECTION 3

PROJECT ORGANIZATION

MANAGEMENT AND STAFFING

The aerometric survey was conducted by a field team which was resident in Abingdon, Virginia for a period of about 20 months. This included time to assemble equipment and supplies on-site, to set up and shake down the sensing and data collection equipment, to operate and maintain the equipment over the operating period, and to disassemble and remove the equipment at the end. The primary management of the field operation and various support functions were performed from the main offices in Gaithersburg, Maryland, where specialists in instrumentation, procurement, and data processing were available as needed. The project manager exercised direct management of personnel, supplies and funds and kept the Government project officer, the power plant personnel, local authorities and other interacting parties informed of the project's needs and progress. Nearly daily interaction occurred by telephone between field personnel and the project manager.

The system was designed in the main office and coordinated with the Government project officer. It was recognized that the initially designed system was less extensive than was desired and it was allowed to evolve as additional resources became available by increasing the number of monitoring stations from six to eight and by adding additional sensors for pollutants and meteorological conditions. Basically, the system consists of fixed monitoring stations, which operate continuously and automatically and which transmit data to a central site, and mobile monitoring stations which are moved to be in the vicinity of the plume during each operating period. The details of the system and how it is operated are described in Section 4, FIELD MEASUREMENTS PROGRAM.

The number of people who were resident at the monitoring site varied from three to five, but generally consisted of four people. A field crew supervisor was responsible for coordinating the activities of people at the site, for reporting problems and progress to the project manager, and for interacting with the project manager in planning future activities. Small procurement actions for supplies and minor maintenance services were performed by the field staff, but all procurements were subject to the approval of the project manager. The primary functions of the field crew were operating a mobile van, taking upper air observations, maintaining the sensors and data processing equipment, record keeping, and filing and shipping of data and supplies. One member of the field crew was responsible for running the mobile van, one was responsible for maintenance of equipment, and two were responsible for upper air observations. The two responsible for upper air observations also performed record keeping, data handling functions and support to the maintenance and mobile van operations as needed.

Airborne monitoring was performed during two intensive 10-day monitoring periods. The field staff was increased to eight members for these operations. This permitted two men to be assigned to the helicopter operations, one man to coordinate information at the central processing site and one man to help with the increased load of errands and data records. A helicopter was leased from the Appalachian Flying Service, who furnished a pilot and provided assistance in installing the instrumentation in the helicopter. The helicopter was based at the Tri-City Airport, near Bristol, Tennessee. Each day's airborne operation began at the airport. However, subsequent refueling was arranged at a local helicopter pad at Lebanon, Virginia. The convenient refueling greatly increased the amount of flying time devoted to sampling operations.

Other organizations who assisted in the execution and support of the monitoring operations included the following:

- U.S. Environmental Protection Agency--Provided resources for the study, advice on instrumentation and field activities, guidance for selection of alternatives, and critical review of all activities.
- American Electric Power Company and its subsidiary, Appalachian Power Company--Provided office and storage space, use of company grounds, security for vehicles and trailers, data on plant operations and facilities, advice on plant operating characteristics, and critical review of monitoring data.
- Appalachian Flying Service--Contracted to GEOMET for helicopter service.
- Midwest Research Institute and PEDCo Environmental Specialists, Incorporated--Contracted to GEOMET for sulfate analysis of hi-vol filters.
- Research Triangle Institute--Contracted to EPA to field audit the monitoring equipment.
- Engineering-Science, Incorporated--Contracted to EPA to measure stack gas characteristics as a check of other available measurements.

FIELD OPERATIONS

The field monitoring system was designed to include both stationary and mobile sampling systems. This permitted conventional stationary ground-level observations to be supplemented by observing stations which are moved directly into the path of the plume during routine daily sampling operations. The monitoring network was fully instrumented with meteorological sensors in order to permit micrometeorological influences induced by the complex terrain to be observed. The emission characteristics of the plant's two stacks were determined by direct measurements of NO and SO_2 concentrations in one stack as a part of the automated monitoring network and by measurements of air temperature, boiler intake, air flow rates, generator output loads, fuel consumption and fuel sulfur content, which are taken by the plant.

The fixed monitoring network provides a continuous record of how emissions from the plant affect a number of selected locations. Eight locations were selected because of their relation to terrain characteristics which are expected to influence the plume of plant emissions. A part of the field operation was concerned with keeping these observing stations operating properly. These stations collect a large amount of data with a relatively small amount of manual support.

The fixed station sampling was supplemented by mobile sampling in which the sampling station is moved to locations where the plant plume can best be observed. Ground sampling in a mobile van was usually performed 4 or 5 days a week. Most of the sampling was performed during the day, but some nighttime sampling was carried out. Two types of ground mobile sampling strategies were used. In one strategy the samples were collected in a moving state. This allowed a large number of different locations to be sampled in a short time to help define the width and length of the area in which the plume was present at ground level. The second strategy was to park the van at an opportune spot to provide a 1-hour sample which supplements the observations available from the fixed stations. A mobile sampling station requires continuous manual supervision and produces data directly proportional to the amount of manning time assigned. However, unlike the fixed stations, which only observe the plume when the wind is carrying the plume to the station, the mobile station can be moved to a good observing location (within limits imposed by available roads) so that it is usually observing the plume. The fixed stations are most suited to observing long-term plume effects, while the mobile stations are most suited to observing short-term plume effects. Both types of observation were important parts of this program.

While ground-based meteorological measurements were continuously measured at the fixed monitoring stations, upper air measurements were obtained from balloons. These measurements require continuous manual supervision and were made during daylight hours. They provide a valuable supplement to the ground-based meteorological measurements from fixed stations by adding a vertical dimension to the meteorological data base.

The most comprehensive set of observations during the field operation was obtained by helicopter sampling. These observations allow the plume to be measured in three dimensions. These data provide the most detailed picture of plume behavior. It is planned that the plume behavior observed by helicopter will be used to interpret plume behavior during other periods in which the plume is partially observed by the fixed and mobile ground sampling stations.

In summary, the field program was organized to include fixed and mobile ground sampling stations, emissions data from the plant, upper air meteorological data and airborne sampling. The equipment and supplies necessary to carry out the program were procured and set up in the vicinity of the Clinch River Steam Plant in Carbo, Virginia. The program was conducted by a four-man field crew resident at the site and supported by specialized services in management procurement and data processing in the home office and by various services provided by the plant, by a helicopter service, by an analytical laboratory and by maintenance and supply organizations as required.

SECTION 4

FIELD MEASUREMENTS PROGRAM

SYSTEM CHARACTERISTICS

The field program consisted of five distinct activities: continuous data collection at eight fixed stations, frequent collection using a mobile monitoring unit for surface observations, T-Sonde/Pibal observations, scheduled use of a helicopter monitoring unit for airborne observations and collection of plant operating parameters. Data were collected over a 16-mo period.

The actual number of fixed stations was determined by the cost and manpower required to maintain each station. The general design criteria for the fixed station monitoring sites were:

- Wind speed, wind direction, temperature, SO_2, NO and NO_2 concentrations were to be continuously measured near ground-level (within 10 m).
- Frequency of occurrence of concentrations above detection thresholds was to be high; 10 percent or more was the goal.
- Three monitoring sites were to be oriented to measure variations in the ratio of SO_2 to sulfate and NO to NO_2 concentrations with distance from the power plant.
- Two monitoring sites were to be oriented to measure valley-ridge concentration differences.
- Three monitoring sites were to be oriented to measure concentrations for different roughness fetches; e.g., upvalley, downvalley, crossvalley.
- One site was to detect presence of valley drainage flow.
- Two sites were to measure plume impingement on ridges.

- Sulfate was to be measured on request in hourly samples; system had to be capable of collecting 24 hours of sulfate samples, unattended.

- Two sites were to include 100-foot towers for measuring vertical variation in temperature and/or wind.

- The sites had to be accessible for setting up equipment and shelters and for electricity and telephone service; this meant being near a road with residents served by telephone service and electricity.

- Site shelters were to be secure from vandals.

The eight fixed monitoring station locations were selected to meet design criteria for climatology, local topography, existing roadways and utility services, and the ability to negotiate for the land on which to place the instrument shelter. Locations were selected using guidance from dispersion model calculations and representative climatological data. The site locations are contained in Appendix A. Initially only six stations were operational with the Lambert site coming on line on October 27, 1976 and the Johnson site becoming operational November 15, 1976. The Castlewood station washed away in the flood of April 5, 1977. The Lambert instrumentation was installed at Castlewood during July 1977. Site characteristics are summarized in Figure 6 and Table 3, and they are diagrammed in Appendix A.

Site No. 1 was the Tower site which had, in addition to the air quality equipment, a 30 m tower which measured winds at two levels and temperature at three levels. This site was 3.4 km to the northeast of the plant at an elevation of 585 m. The site was in open terrain and air flows in the region were unobstructed by vegetation or nearby terrain features. The nearest terrain feature was a ridge located directly south of the Tower site at about 1 kilometer distance. This was the closest site to the Power Plant and was located 124 m above the base of the plant.

Site No. 2 was the Munsey site which was located a little over 4 kilometers to the southeast of the Power Plant. It was located approximately one-third of the way up the hillside from the valley floor and was placed in that location so that, in conjunction with the Hockey site located on approximately the same line but at 200 m higher elevation, it could assist in resolving the characteristics of the plume as it traveled in that direction.

Site No. 3 was the Nash's Ford site which was located approximately 11 kilometers to the east of the Power Plant in the Clinch River Valley. The site was located on a small plateau between the Clinch River and Thompson Creek. This site was representative of upvalley flows from the Power Plant as well as any wind channeled up the valley.

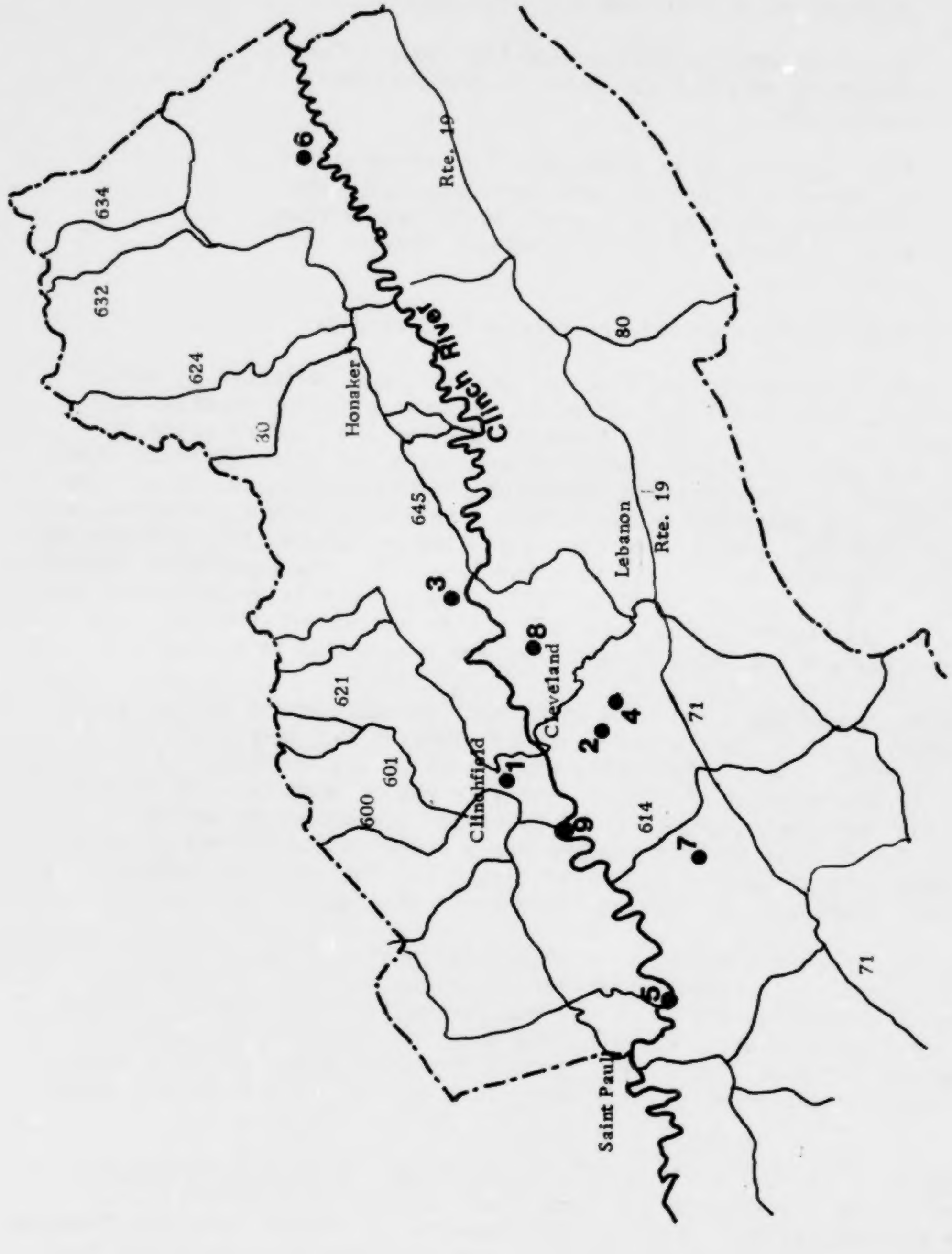

634
632
624
30
Honaker
Clinch River
645
6
Rte. 19
80
Lebanon
Rte. 19
3
8
Cleveland
621
601
600
Clinchfield
1
2
4
71
9
614
7
71
5
Saint Paul

Figure 6. Location of sites.

TABLE 3. MONITORING SITE CHARACTERISTICS

Site Number (see Figure 6)	Site Name	Orientation from Power Plant		Site Elevation		Terrain Characteristics
		Direction	Distance (m)	MSL (m)	Above Plant Base (m)	
1	Tower	46°	3360	585	124	Plateau
2	Munsey	111°	4250	597	136	Valley Side
3	Nash Ford	64°	10820	567	106	Plateau
4	Hockey	107°	5710	792	331	Ridge
5	Castlewood	238°	8280	451	-10	Valley
6	Kent's Ridge	68°	29870	756	295	Ridge
7	Johnson	191°	5760	719	258	Ridge
8	Lambert	82°	7560	597	136	Valley Side
9	Stack	--	0	461	0	Valley

Site No. 4 was the Hockey site which was located on a ridge (792 m msl) just above the Munsey site and on a line with Munsey and the Power Plant. This site was selected to observe the concentration characteristics of the Power Plant plume in relation to a ridgetop.

Site No. 5 was the Castlewood site which was located approximately 8 kilometers west-southwest of the Power Plant. It was very close to the Clinch River, however, it had an unobstructed upvalley view so that winds from that direction would be characteristic of drainage flows if they were occurring. This site was about 10 m below the plant elevation. The station washed away in the flood of April 5, 1977.

Site No. 6 was the Kent's Ridge site which was located 30 km east-northeast of the Power Plant. This site was chosen for both its elevation and distance and was the most distant site from the Power Plant.

Site No. 7 was the Johnson site which was located south-southwest of the Power Plant. This was located on a ridge just to the south of the Power Plant that runs from the west-southwest to the east-northeast. This is the same ridge line that Hockey was located on.

Site No. 8 was the Lambert site and was located approximately one-third of the way up the valley side. It was chosen to determine the plume characteristics in that valley. The instrumentation was moved to Castlewood in July 1977.

A stack monitor was located in the duct work at the base of the Unit 3 stack. The monitor was between the electrostatic precipitators and the base of the stack. Valid data was collected after December 1, 1976.

The data acquisition station and office were located within the Clinch River Steam Plant. The station contained all the equipment for communications with the eight satellite stations, including a small data processing center; further, it housed a facsimile machine for weather maps. All operations were conducted from that station.

Standard Fixed Monitoring Stations

Five standard fixed stations (Nos. 2, 3, 4, 5 and 6) measured SO_2, NO_x, NO, wind speed, wind direction and temperature continuously. Two additional stations (Nos. 7 and 8) monitored SO_2, wind speed and wind direction. The Tower site (No. 1) included a more extensive set of meteorological measurements in addition to the standard fixed station measurements. Supplementary wind information was obtained at Site No. 4 (Hockey). These additional wind data were in the form of wind speed and wind direction at the 30 m level. Equipment for this purpose was supported by a 100-foot guyed tower.

At all sites, the gas analyzer for nitrogen oxides measured total nitrogen oxides (NO_x) and nitric oxide (NO). The difference between the two measurements was recorded as nitrogen dioxide (NO_2). Although all three signals were available from the analyzer, only the NO and NO_x signals were calibrated and processed. The recorded NO_2 value is the difference between the calibrated NO_x and NO values. For every fixed and mobile station measurement of nitrogen oxides, values of NO, NO_x, and NO_2 are available, unless either the NO or the NO_x channel was not operating, in which case only one measurement is available.

Hourly samples of sulfates were collected on request at stations 3, 4, 5, 6, and 7, using a 24-port high volume air sampler.

For gaseous pollutant measurements, air was collected from a height of about 1 m above the roof of the instrument shelter and pumped through a sampling manifold from which it was available to the gas analyzers. The wind and temperature sensors were located at the top of a 5 m tower which was guyed to the roof of the instrument shelter. The resultant sampling height was about 8.5 m above the ground. In general, this has been referred to as a 10 m measuring height in this report. The 24-port high volume air sampler was located on the roof of the instrument shelter.

In addition to the two gas analyzers, the instrument shelter, which was maintained at 20°C, housed a transmuter to condition the meteorological signals, an automated calibrator to dilute and regulate gas flow to the gas analyzers, and a data logger. The data logger digitized analog signals, recognized commands from a central processor, and responded to requests to turn on or off switches or to collect and transmit data. The shelter contained working space for maintenance work and storage space for filters, a log book and miscellaneous supplies.

Access to the roof was obtained by a ladder stored in the shelter. The filters on the particulate samplers located on the roof were changed during the routine twice weekly visits to the shelters by field personnel.

Sulfate sampling could be conducted continuously by collecting hourly averaged samples for up to 24 hours at any remote fixed station without requiring filter collection and replacement. When this equipment was operated continuously, it was necessary for field staff to visit the station once a day for servicing. However, the sequential air samplers were commanded by an operator at the central site to activate collection of an hour's particulate sampling only if the simultaneous SO_2 reading was expected to be high or the station was selected to maintain background levels. We expected that this procedure would permit the operation of most fixed station sulfate sampling units unattended until the regularly scheduled maintenance of the entire fixed station (which was normally twice a week), since sulfate measurements were usually made only during those hours when the plume was in the vicinity of the station.

As a back up to the telecommunication system, NO_2 and SO_2 were continuously recorded on strip charts. The configuration of equipment at each standard fixed monitoring station is illustrated in Figure 7.

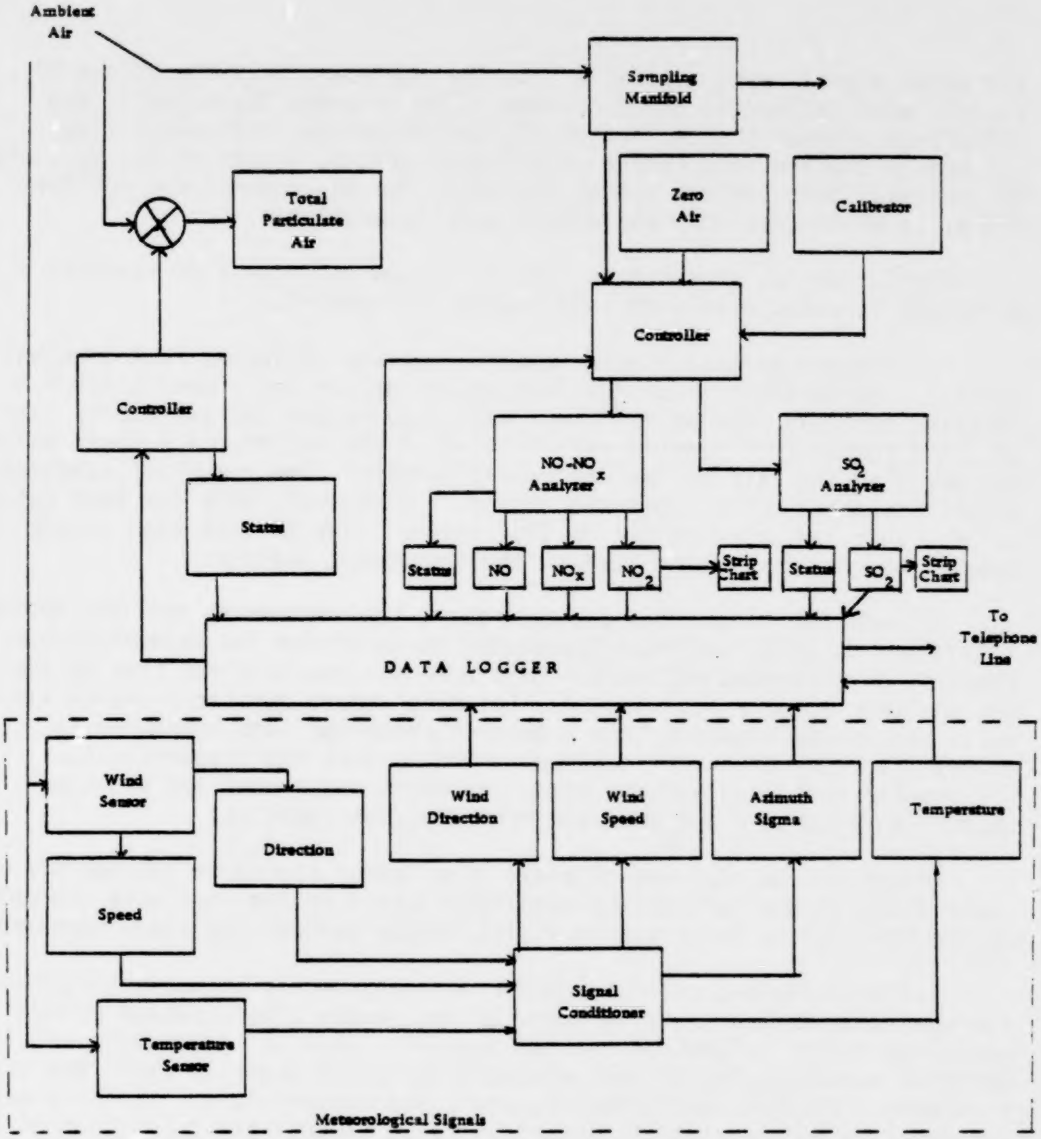

Ambient Air
Sampling Manifold
Zero Air
Calibrator
Total Particulate Air
Controller
Controller
NO-NO$_x$ Analyzer
SO$_2$ Analyzer
Status
Status
NO
NO$_x$
NO$_2$
Strip Chart
Status
SO$_2$
Strip Chart
To Telephone Line
DATA LOGGER
Wind Sensor
Direction
Wind Direction
Wind Speed
Azimuth Sigma
Temperature
Speed
Signal Conditioner
Temperature Sensor
Meteorological Signals

Figure 7. Standard fixed monitoring station configuration.

Tower Monitoring Station

In addition to single-level continuous measurements of SO_2, NO, and NO_x, the Tower station made continuous measurements of wind direction and speed (three dimensions) at two levels (10 and 30 m), temperature at three levels (0.5, 4 and 30 m), and also measured relative humidity, ultraviolet radiation, and precipitation. Relative humidity was measured on the tower at a height of 4 m. Ultraviolet radiation and precipitation were measured at appropriate points with unobstructed exposures due to vegetation, terrain or man-made structures. The tower was approximately 30 m tall and was supported by a concrete base. Except for the meteorological items, the Tower monitoring site was configured like the other standard fixed monitoring stations. Figure 8 illustrates the processing of meteorological measurements.

Stack Monitoring Station

Exhaust gases exiting the number 2 stack at the Clinch River Power Plant were continuously monitored by an in situ gas analyzer beginning November 4, 1976. The sampler was located in the breeching leading from the electrostatic precipitator to the stack. Sampling was performed on gases exhausted to the stack serving one boiler rather than the stack serving two boilers in order to simplify the relationship between boiler operating characteristics and the exhaust gas measurements. The signals were digitized and transmitted to the central station by the same procedure used at other remote sites.

Central Data Acquisition

The data acquisition system for the fixed station network utilized leased telephone lines for telemetry from the satellite fixed stations and a minicomputer at the data acquisiton station for data processing and system control. Each fixed monitoring station had a Monitor Labs 9400 remote data logger with scanner, analog to digital converter, and telemetry interface. The central data acquisition station processing and control system was a Monitor Labs 700 Ambient Data Acquisiton System controlled by a Data General Nova Computer 2/10 with 24 K core storage and with automatic memory protection, program loading, and restart. System time was established and maintained through any power outages by a Monitor Labs 3100 digital clock with automatic battery power backup. The Nova Computer could be controlled, programmed, and interrogated by a console printer which provided automatic and requested data printout. Computer-edited and processed data were stored on a magnetic tape ready for subsequent analysis on a larger computer. The satellite stations reported data on query from the computer at a scan rate of one complete cycle per 2 min. Any values desired by the resident meteorologist could be printed out on request via the printer and the program was protected against operator error. The base station automatically controlled the air quality analyzers for zero readings and single value calibrations. These routine zero/calibration readings were programmed to be taken once a day, shortly after midnight, but could be initiated at any time on operator request.

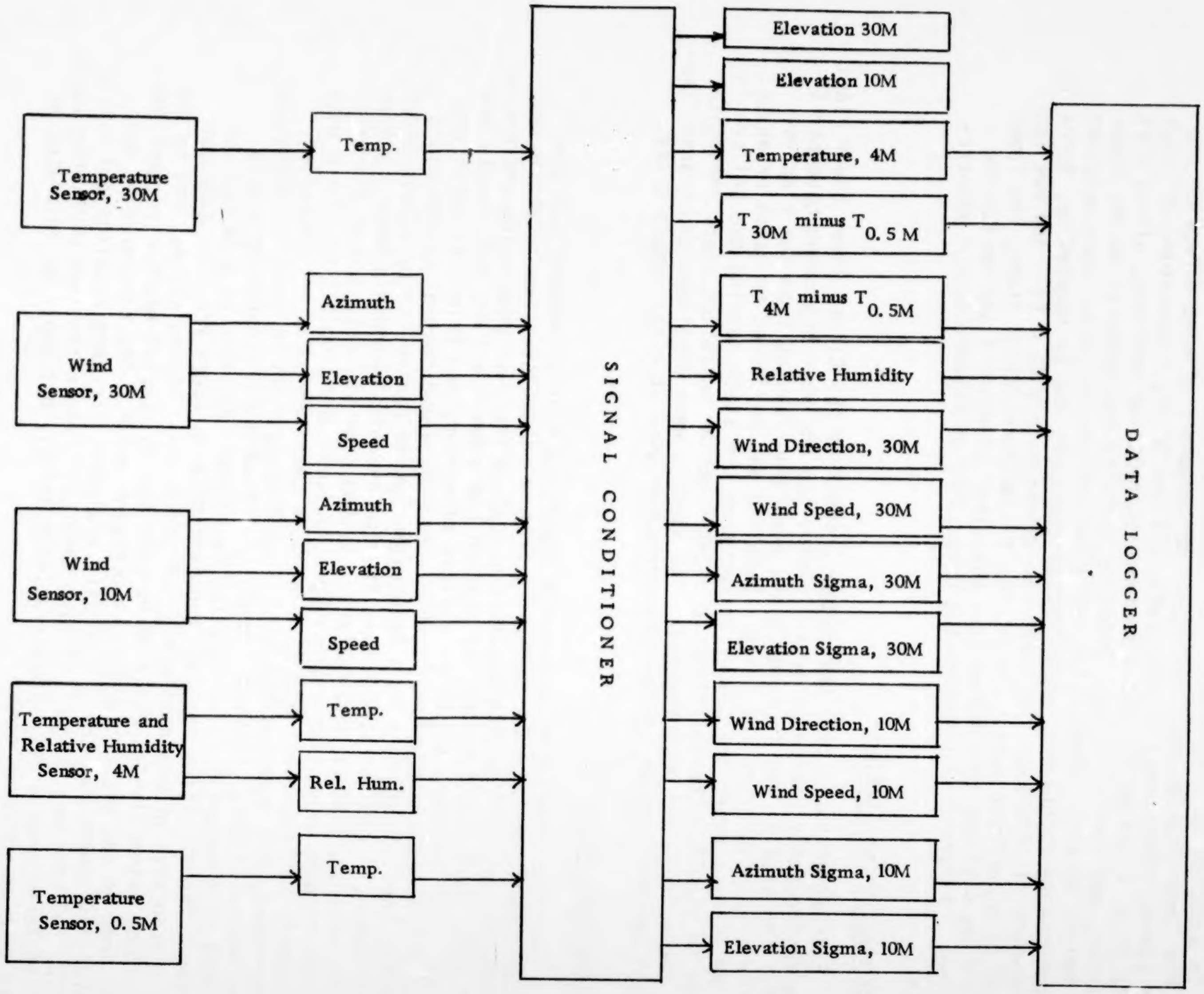

Temperature Sensor, 30M
Wind Sensor, 30M
Wind Sensor, 10M
Temperature and Relative Humidity Sensor, 4M
Temperature Sensor, 0.5M
Temp.
Azimuth
Elevation
Speed
Azimuth
Elevation
Speed
Temp.
Rel. Hum.
Temp.
SIGNAL CONDITIONER
Elevation 30M
Elevation 10M
Temperature, 4M
T_{30M} minus $T_{0.5M}$
T_{4M} minus $T_{0.5M}$
Relative Humidity
Wind Direction, 30M
Wind Speed, 30M
Azimuth Sigma, 30M
Elevation Sigma, 30M
Wind Direction, 10M
Wind Speed, 10M
Azimuth Sigma, 10M
Elevation Sigma, 10M
DATA LOGGER

Figure 8. Tower monitoring station meteorological signals.

The system interrogated the sensors once every 2 minutes. Hourly averages, 2-minute values and peak values were stored on magnetic tape for further processing. Meteorological parameters were treated similarly. The configuration of monitoring stations and the equipment at the central data acquisition station is shown in Figure 9.

Equipment Used at Fixed Stations

Part or all of the following equipment was located in each of the stations:

- SO_2 Analyzer - Monitor Labs (ML) Model 8450
- NO/NO_x Analyzer - ML Model 8440
- Total Particulate Sampler - Misco Special 24 Head Sequential High Volume Air Sampler
- Wind Sensor - Meteorology Research, Inc. (MRI) Model 1022
- Temperature Sensor - MRI Model 815-1
- Data Logger - ML Model 9400
- Meteorological Signal Conditioner - MRI Model 1002 with circuits for wind direction (540°), wind speed (0 to 100 mph), azimuth sigma (0 to 45°) and temperature (-30° to 50°C)
- Strip Chart Recorder (2 pen)
- Calibrator and Controller - ML Model 8500
- Instrument Shelter - Spacemaster, Special 8' x 12' Trailer
- Tower - MRI Model 1412-18 Tripod
- Miscellaneous Supplies (cable, mounting arms, tubing, manifolds, blower, gases, filters, etc.).

The performance characteristics of each of the above sensing instruments and all others used in this study are described in Appendix B.

The Tower monitoring station was identical to the other fixed monitoring stations except that the meteorological sensors were replaced by a more extensive set of sensors which were located on a 30-m tower rather

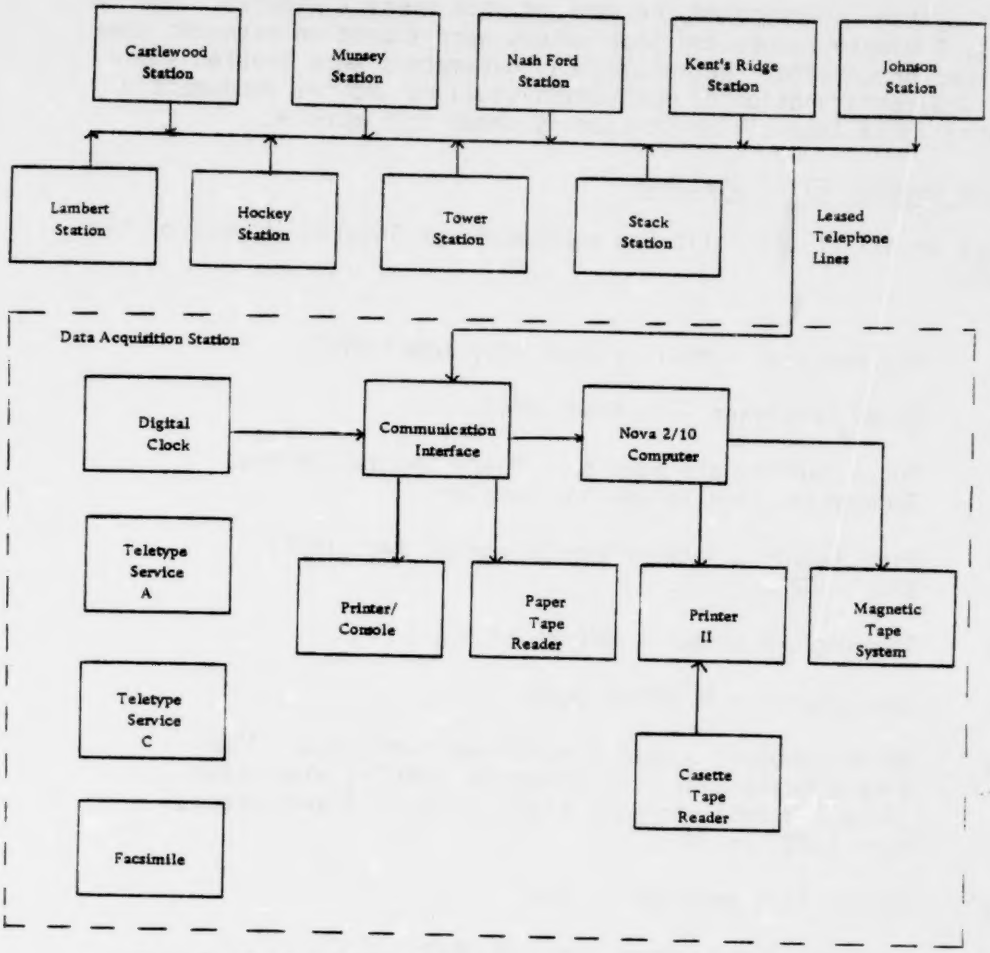

Castlewood Station
Munsey Station
Nash Ford Station
Kent's Ridge Station
Johnson Station
Lambert Station
Hockey Station
Tower Station
Stack Station
Leased Telephone Lines
Data Acquisition Station
Digital Clock
Communication Interface
Nova 2/10 Computer
Teletype Service A
Printer/ Console
Paper Tape Reader
Printer II
Magnetic Tape System
Teletype Service C
Casette Tape Reader
Facsimile

Figure 9. Fixed station network data acquisition station configuration.

that a 5.5 m tripod on top of the instrument shelters. At the Tower site the following equipment was used in place of the standard station meteorology equipment:

- Wind Sensors (2) - Meteorology Research, Inc. (MRI) Model 1053
- Temperature and Relative Humidity Sensor - MRI Model 815-4
- Temperature Sensors (2) - MRI Model 815-2
- Precipitation Sensor - MRI Model 370 Tipping Bucket Rain Gage (heated)
- UV Radiometer - International Light, Inc. Model PT100-CM108 #600 Photodetector
- Meteorological Signal Conditioner - MRI Model 1001 with circuits for wind azimuth (540°), wind elevation (±60°), wind speed (0 to 100 mph), azimuth sigma (0 to 45°), elevation sigma (0 to 15°), differential temperature (±5°C), temperature (-30° to 50°C), relative humidity (0 to 100%), and rain accumulation (0.0 to 1.00 in)
- Tower (30 m) - Special Installation.

The Hockey site was identical to the other sites except that it had an additional MRI Model 1022 wind set mounted on top of a 30-m tower.

The following equipment was used to measure and record stack gas concentrations:

- Stack Gas Analyzer - Environmental Data Corporation Monitor for SO_2 and NO
- Data Logger - Monitor Labs Model 9400
- Strip Chart Recorder (2 Pen)

Table 4 gives a listing of the nine fixed ground stations and the measurements at those sites. Detailed specifications for each major equipment item are given in Appendix B.

Equipment located at the base station for accumulating data from all remote sensing stations and for controlling all field monitoring activities included the following:

TABLE 4. SUMMARY OF MEASUREMENTS AT FIXED MONITORING SITES.

	SO_2	NO_x	NO_2	NO	Temp (10m)	Temp $(T_4-T_{0.5})$	Temp $(T_{30}-T_{0.5})$	Wind Speed (10m)	Wind Direction (10m)	Wind Speed (30m)	Wind Direction (30m)	Standard Deviation of Wind Azimuth (10m)	Standard Deviation of Wind Elevation (10m)	Standard Deviation of Wind Azimuth (30m)	Standard Deviation of Wind Elevation (30m)	Relative Humidity	Total Particulate	UV Radiation	Precipitation
Tower	X	X	X	X	X*	X	X	X	X	X	X	X	X	X	X	X		X	X
Munsey	X	X	X	X	X			X	X			X							
Nash's	X	X	X	X	X			X	X			X					X		
Hockey	X	X	X	X	X			X	X	X	X	X		X			X		
Castle	X	X	X	X	X			X	X			X					X		
Kents	X	X	X	X	X			X	X			X					X		
Lambert	X							X	X			X							
Johnson	X							X	X			X					X		

* Temperature of Tower recorded at 4m

- Data Acquisition System - Monitor Labs Model 7000 including computer interface (ML4100), digital clock (ML3100), leased-line modem interface (ML4400L), software (ADAM III), high-speed printer interface (for Decwriter) and paper tape reader interface (CP49)
- Computer - Data General NOVA 2/10.
- Uninterruptible Power Supply - Elgard Model 102-1
- Magnetic Tape System - Data General Model 6021
- Printers (2) - Decwriter Model LA35 and LA36
- Paper Tape Reader - Remex Model 6300
- Casette Tape Reader - Metrodata Model DL625 with Interface to Decwriter
- Teletypes (2) - Series A and C (discontinued in November 1976)
- Facsimile - National Weather Service Fax
- Pibal Theodolites (2)
- T-Sonde receiver and T-Sondes
- Miscellaneous supplies (cable, balloons, magnetic tape, printer paper, etc.)
- Two-way radio.

Surface Mobile Sampling

Mobile ground sampling was conducted in accordance with the following criteria:

- Concentrations of SO_2, NO, NO_2, and O_3 were to be continuously monitored for 1 hour at stationary locations within the footprint area (i.e., all ground locations where the ambient concentration exceeds the sensing threshold of the analyzers).
- A 1-hour particulate sample (for sulfate analysis) was to be collected at each stationary location.

- Wind speed and direction and temperature were to be continuously recorded at each stationary location.

- Temperature and SO_2 concentration were to be continuously recorded using fast response sensors throughout all mobile traverses with locations periodically annotated on the recorders. The traverses were to include a valley to ridge pass which emphasized vertical variations, if possible.

- Sampling operations were to be scheduled to give primary emphasis to reasonably steady meteorological conditions with secondary emphasis on transient conditions.

- Stationary sampling locations were to be selected to maximize the type of information which was appropriate to the dispersion situation being observed and to complement the fixed station monitors. Some specific types of information sought were the following:

  -- Ratio of sulfate to SO_2 and NO to NO_2 concentrations with increasing distance from plant

  -- Valley to ridge concentration differences

  -- Plume axis ground concentration profile for varying distance from the source

  -- Influence of valley circulation on ground concentrations from the plume

  -- Influence of terrain roughness on plume dispersion

  -- Interaction of terrain roughness and meteorological conditions on plume dispersion.

  The latter two types of information sometimes resulted in the selection of a location in order to obtain data which was comparable with another sampling day.

- Mobile sampling was to be conducted for 5-1/2 hours a day, 4 days a week.

The surface mobile sampling unit provided data for three important aspects of the monitoring effort. First, the mobile monitor was able to survey the area upwind of the source to provide a background reference for all concentrations. Second, the mobile sampling afforded a much better resolution of the concentration patterns at the surface by filling in data points between the fixed station locations and in places of special interest such as along ridges or in lower areas where the effects of drainage air flow could be studied. Third, the mobile unit provided the opportunity to search for and define the peak concentration areas affected by the plume.

The following equipment was used for mobile ground sampling:

- NO/NO_x Analyzer - Monitor Labs (ML) Model 8440
- SO_2 Analyzer - Theta Sensor, Inc. (TSI) Model 7111-1051
- Ozone Analyzer - ML Model 8410
- Particulate Sampler - Misco Model 8000
- Meteorological System - Climatronics Corporation Electronic Weather Station (included wind speed, wind direction, and temperature sensors, signal conditioner and recorder)
- Data Logger - Metrodata Model DL 640
- Power Supply - Homelite Model 130A22-1D 2250-watt generator
- Strip Chart Recorders (4) - Esterline Angus Miniservo Model S22243
- Van - Chevrolet Suburban Model CK10906
- Miscellaneous Supplies (cable, mounting arms, tubing, manifolds, blower, gases, filters, batteries, strip charts, casette tapes, etc.)
- Two-way radio.

Detailed specifications for each major equipment item are given in Appendix B.

Airborne Mobile Sampling

The following airborne mobile sampling was performed by helicopter:

- SO_2, NO, NO_2, and O_3 concentrations; temperature and relative humidity were continuously measured during selected periods of each flight.

- Measurements of SO_2, NO_x, and O_3 were visually displayed for an observer accompanying the helicopter pilot to help locate the plume and to keep track of vertical and horizontal positions of passes through the plume.
- Plume concentrations were measured at several distances downwind varying from 0.1 to 15 km.
- Measurements were made in two 7- to 10-day periods, one period in the late fall and the second in midsummer.

The helicopter sampling was used to measure vertical and horizontal profiles of SO_2, NO and NO_2, temperature, humidity and O_3 in the plant plume.

The helicopter sampling program had two major objectives associated with its use; the first objective related to plume identification and plume chasing; the second major objective was plume definition.

The plume identification phase of this program consisted of flying the helicopter in such a mode so as to identify the bounds of the plume at various distances downwind. This technique simply consisted of a flight through the plume taking measurements while the helicopter was traversing the plume. One purpose of this type of measurement was to identify the distance downwind that the plume could be tracked in its composite form and to identify the path of the plume relative to the complex terrain.

The plume definition phase consisted of detailed cross-sectional profiles of the plume at various elevations. Once the plume had been identified, continual traverses at different heights through the plume were made so as to define the detailed characteristics of the various parameters in the plume.

The following equipment was carried in a helicopter for airborne sampling:

- SO_2 Analyzer - Theta Sensor
- NO/NO_x Analyzer - Monitor Labs (ML) Model 8440
- O_3 Analyzer - ML Model 8410
- Meteorological and Navigational Data System - Metrodata Model M-8 with sensors for airspeed, altitude, temperature and humidity
- Data Logger - Metrodata Model DL640

- Power supply
- Two-way radio
- 3 strip chart recorders
- Miscellaneous supplies (cable, tubing, gases, filters, batteries, strip charts, cassette tapes, etc.)

Detailed specifications for each major equipment item are given in Appendix B.

OPERATING PROCEDURES

This section describes the detailed procedures for performing the various field activities that were necessary for the successful completion of the field portion of this project. Included also are forms that were used in carrying out the various assignments.

Base Station Operations

The base station served as a coordinating center for the operations of all other aspects of the study. Here, daily operations were discussed and altered as necessary to accommodate special events or problems. Each day a two-sheet report (Figure 10) was completed to summarize the day's activities. The base station housed facilities for the data acquisition system, FAX machine, Service A and Service C teletypes, reduction of Pibal and T-Sonde data, and for computing the plume projection.

Data Acquisition System

At the base station a computer performed the continuous and automatic running of the data acquisition system. The data acquisition system had a prescribed routine schedule of functions which consisted of interrogating all fixed station sensors every 2 min. This was the normal mode of operation. The routine schedule could be interrupted by operator request to perform special functions. These functions sometimes were to alter the routine schedule, to interrogate any of the sensors, to modify the automatic processing of collected data, or to add or delete sensors from the interrogation list.

The control system received inputs at the control station from a console, a paper tape reader, a magnetic tape unit, or telephone lines. The control system sent outputs to a printer, a magnetic tape unit, or telephone lines. The telephone lines were connected to the data loggers at each monitoring station. Data from all the remote sites were telemetered to the base station for processing and storage via leased telephone lines. The base station contained the central processing unit with a printer for real time display and for system checkout, and a tape recorder for data storage.

DAILY PROJECT REPORT

Clinch River Power Plant Plume Study Project
Carbo Field Office

Julian Day ________________ Gregorian Date ________________

Report Prepared by:

Field Staff Members Present:

Major Activities Performed:

Mobile Ground Runs

Unit 1 (SO_x, NO_x, O_x), (where)
Unit 2 (SO_2 only), (where)

Pibal Taken, (when)

Routine Station Maintenance - Stations Visited

Sulfate Sampling

Date Preparation and Analyses

Other Routine Activities

Project Visitors:

GEOMET Home Office Staff: (who)
Other Visitors: (who)

Special Events and Problems:

Staff or Equipment Shortages

Unusual or Pollution Events

General Weather Condition:

Logistics:

Material Ordered

Material Received

Material Shipped

(continued)

Figure 10. Form to report day's activities

DAILY PROJECT REPORT
(Continued)

Major Equipment Status

X = equipment for that parameter not at that station

Enter (in decimal form) the portion of 24-hours that sensor operated normally e.g., .7 = normal operation for 16 hours.

* Entries for Part. = A/B where A is time sampler is operable; B = time equipment was operated (time is fraction of 24-hours in decimal form).

	DL 9400	SO_2	NO_x	NO_2	NO	WS1	WD1	SG1	TM2	Part.	RH	PCP	EL1	SE1	DTI	WS3	WD3	EL3	SE3	DT3	SG3	Dichot.	O_3
TOWER																						X	X
MUNSEY										X	X	X	X	X	X	X	X	X	X	X	X	X	X
NASHS											X	X	X	X	X	X	X	X	X	X	X		X
HOCKEY											X	X	X	X	X			X	X	X			X
CASTLE											X	X	X	X	X	X	X	X	X	X	X	X	X
KENTS											X	X	X	X	X	X	X	X	X	X	X		X
JOHNSN			X	X	X				X		X	X	X	X	X	X	X	X	X	X	X	X	X
LAMBER			X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
VAN 1											X	X	X	X	X	X	X	X	X	X	X	X	
VAN 2			X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
STACK			X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

EQUIPMENT MALFUNCTIONS:

* For example 1/.33 means sampler was available 24 hours and operated 8 hours.

Figure 10. (concluded)

The condition of each sensor at each monitoring site was continually observable on the routine data printout at the central station. Each sensor was routinely checked, verified and logged at least twice a day. Each such checkout period included reading a sequence of measurement values for each sensor at each site to demonstrate that the sensors were performing meaningfully. Meteorologists technically trained in instrument operation evaluated these readings. Any discrepancies observed were checked by visiting the appropriate site and taking necessary corrective actions.

Replacement parts for key components of the system were maintained on site. Maintenance agreements were arranged for all system components. Equipment was occasionally moved from one site to another to keep sites which were exposed to the plume in operation as much as possible.

A log of all computer interventions (Figure 11) was kept to have a complete understanding of all information recorded on magnetic tape. A copy of this log is included and is self-explanatory. In addition, the operator asking for the intervention initialed all entries.

In addition to the above data gathering system operations, routine meteorological observations were noted in a daily log by an observer during duty hours. This helped with later data interpretation, especially during the significant mobile ground sampling periods. Vertical profiles of wind speed, direction and temperature were observed by double theodolite pilot balloon observations supplemented by single theodolite observations and T-Sondes. Data on the power plant operating conditions were routinely obtained from the plant personnel.

Plume Projection Techniques--

To aid in determining probable locations for stationary sampling for Mobile I, a plume projection technique was developed. This technique used the clear plastic-covered topographic maps as mounted on the wall of the main office. The projection of the plume was then plotted on this clear plastic with grease pencils.

The projection usually started at around 5:00 or 6:00 in the morning, depending somewhat on the wind speed. For high wind speed conditions, only about 2 previous hours needed to be plotted. A color scheme for grease pencils was selected so that a particular hour then remained the same color for various plots of the plume on the chart. Each hourly update was then plotted on the topographic maps leaving the previous plume projections on the plastic so that a trend could be observed in terms of plume movement through the day.

The technique itself consisted of calculating the distance that the plume would traverse in 1 h by using the upper level wind at either the Hockey or Tower site. Generally, the Hockey site seemed to be more indicative of the travel of the plume. However, the meteorologist would

COMPUTER INTERVENTION LOG

Date	Intervention Time	Return to Normal Time	Reason for Intervention

Figure 11. Form to report computer interventions.

consider both the Tower and the Hockey site winds using his local experience to determine the best value under various meteorological conditions.

Sulfate Sampling--

The sulfate sampling program was also directed from the base station. The sulfate monitoring decision process is shown schematically in Figure 12.

Each morning, as the plume projection was plotted on the wall map, decisions were made as to potential samplers that might be turned on during that day that would be in a downwind position of the power plant plume. The synoptic situation from the facsimile data was also reviewed in deciding whether specific samplers would be activated or not. Sulfate samplers both upwind and downwind of the plant were usually activated on selected days.

The selected sulfate samplers were turned on through the DEC writer attached to the computer. Once the samplers were activated, the decision to leave a sampler on or activate additional sulfate samplers was reviewed on an hourly basis. If the variation of the plume was such that it appeared that it would not be returning to the direction of one of the samplers that had already been activated, generally a 3-hour time span was allowed to elapse before turning the sampler off. The reason for this elapsed time was related to the uncertainties of the plume projection position and to the possible low-level drift of residual sulfates that might have been in the area from earlier positions of the plume.

A criterion to activate a sulfate sampler was that the wind direction was within ± 45° of the stationary sampling location. This decision was tempered somewhat by the steadiness of the plume and extensive field experience. If the early morning decision was to not activate any sulfate samplers, a review of that decision was made at noon based upon additional wind observations. If the samplers were activated, the hourly review procedure was followed. If the noon decision was not to activate any samplers, then at 4:00 p.m. another review was made to determine whether any samplers should be activated for an overnight sampling period.

This 4:00 p.m. review was made on all days using the same criteria as stated above; however, a longer period of forecast was necessary since this required a decision that would influence the next 14 to 16 hours (5:00 p.m. through 9:00 a.m. the next morning).

This sulfate monitoring decision process is shown schematically in Figure 12. The on and off times for each sulfate monitor are recorded automatically by the computer and printed on the computer output record.

Fixed Monitoring Network Operations

The daily operation of the fixed station monitoring network consisted mainly of routine instrument maintenance and calibration. If a malfunction was detected in any instrument in the system, it was given early attention

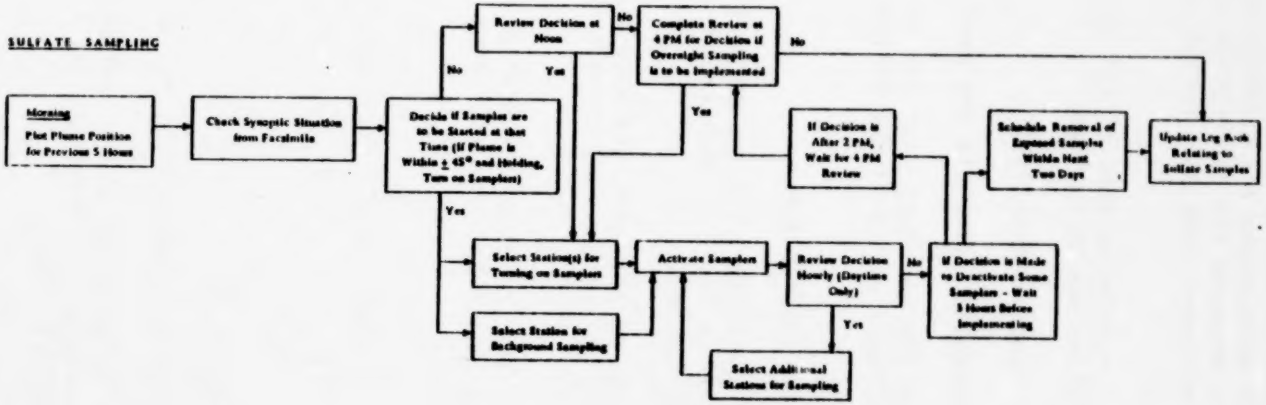

SULFATE SAMPLING
Morning
Plot Plume Position for Previous 5 Hours
Check Synoptic Situation from Facsimile
Decide if Samples are to be Started at that Time (If Plume is Within ± 45° and Holding, Turn on Samplers)
No
Yes
Review Decision at Noon
No
Yes
Complete Review at 4 PM for Decision if Overnight Sampling is to be Implemented
No
Yes
Select Station(s) for Turning on Samplers
Select Station for Background Sampling
Activate Samplers
Review Decision Hourly (Daytime Only)
No
Yes
Select Additional Stations for Sampling
If Decision is Made to Deactivate Some Samplers - Wait 3 Hours Before Implementing
If Decision is After 2 PM, Wait for 4 PM Review
Schedule Removal of Exposed Samples Within Next Two Days
Update Log Book Relating to Sulfate Samples

Figure 12. Decision process for operating sulfate samples

by the field personnel in order to minimize any data loss that could occur. The maintenance and calibration schedule was designed so that each of the eight fixed stations received both maintenance and calibration every 7 d. In addition, the maintenance visit preceded the calibration visit by a minimum of 2 d to insure stable instrument responses during calibration.

Walk-in Form--

A form was provided to keep a running account of all equipment at a station. The procedure for completion was as follows:

1. Enter station and obtain station check list.
2. Without changing any information, complete the check list.
3. Make a comparison between the new check list and the previous form which will be found on top of the Monitor Labs 8450 Sulfur Analyzer.
4. Note any changes that have taken place.
5. If changes have taken place restore the system to the original status which will be found in the station and meteorological equipment log book.
6. Change the hi-vol filters, if required, and note status of filters. Bring replaced filters and form to main office for mailing to laboratory.
7. Leave the updated check list on top of the Monitor Labs 8450 Sulfur analyzer and return the previous check list to the main office file.

Station Log--

Log books were kept at all stations for all equipment. They were titled as follows:

1. 8450 (Sulfur Analyzer)
2. 8440 (Oxides of Nitrogen)
3. Station and meteorological equipment (9400, Met equipment).

Any visit to a station had to be logged in the appropriate book. If any work was done or changes were made, the procedure had to be carefully outlined in the log. Every entry included:

1. Time out of service
2. Reason for outage or nature of repair

3. Person's initials

4. Time back in service.

Maintenance Procedure--

General maintenance was performed at all stations on a regular basis. This work was kept up to date to prevent major periods of down time.

The following procedure was used when a general maintenance visit was made:

I. 8450 - SO_2

A. General Inspection

1. Does it respond to span gas?
2. Electrical test?
3. Optical test?
4. Lights on?
5. H_2 flow ok?

B. Internal Inspection

1. Synchronous motor running quietly?
2. Chopper belt ok?
3. Pump operating?
4. Recorder and DAS outputs ok?
5. Change burner filters?
6. Water in exhaust?

II. 8440 - NO_x-NO

A. General Inspection

1. Response to span gas?
2. Electrical test?
3. Optical test?
4. Lights on?
5. NO_x, NO, O_3 flows ok?
6. Converter light work?
7. Vacuum ok?

B. Internal Inspection

1. Change dryrite?
2. Change converter catalyst?
3. Change intake filter?
4. Synchronous motor ok?
5. Chopper drive ok?
6. Pump ok?
7. Gelman charcoal filter ok?
8. Span-Zero valves work?

III. 8500 - Calibrator

A. General Inspection

1. Flows on each channel ok?
2. Temperature ok?
3. Switch in run position?
4. NO system pressure?

B. Internal Inspection

1. Pump ok?
2. Charcoal ok?
3. Permeation tubes ok?
4. Filters ok?
5. Ozone light ok in Ozatrog?*

IV. 9400 - Data Logger

1. Scan properly?
2. Carrier light?
3. Channel assignment ok?
4. Check all channels for following output ranges. Data should fall within these limits:

0	SO_2	0-10v
1	NO_x	0-10v
2	NO_2	0-10v
3	NO	0-10v
4	WSI	0-5v
5	WDI	0-5v
6	SGI	0-5v
7	Temp I	0-5v
8	SO_4	0-9v; UV @ Tower 0-1v
9	RH	0-5v
10	PCP	0-5v
11	ELI	05-v-v
12	SEI	0-5v5v
13	DTI	0-5v5v
14	WS III	0-5v
15	WD III	0-5v
16	EL III	0-5v
17	SE III	0-5v
18	DT III	0-5v
19	SG III	0-5v

---

* Ozatrog is a process which generates ozone.

V. Station

A. Change glass wool at air intake

B. Clean air conditioner filter

C. Check HiVol for proper operation

D. Check tension on tower support wires

E. Check NO + H_2 tank pressure

F. Clean trailer and empty trash.

Mobile Ground Monitoring

Operating Procedures--

The mobile sampling operations were scheduled to observe the power plant plume under a variety of meteorological dispersion conditions, and included early morning, afternoon, and evening periods. Initially, three people were employed in the operation, two in van (Mobile 1) unit and one at the central site. Having two people in the mobile unit allowed one person to continuously monitor the instruments, while the second person drove the vehicle through areas affected by the plume and searched for possible stationary sampling sites. However, when the upper air program was intensified, the number of people in the mobile unit was dropped to one. This person had the responsibility of driving the mobile unit to areas downwind of the plant and setting up the unit for stationary sampling in those areas. Radio communications were used between the mobile unit and the central site to pass up-to-date information from the monitoring network and the facsimile receiver to the mobile unit operator.

Prior to each ground sampling operation there was a period for planning and setting up the operation. During this period the three (sometimes two) full-time people at the site reviewed data from the network monitoring system and the NWS weather facsimile (45 charts per day), made a local observation of winds (up to 3,200 ft) using a pilot-balloon and a double theodolite, predicted plume behavior for the next 6 h, selected the mobile sampling route, and set up equipment for the mobile unit. Prediction of plume behavior took into account present and predicted estimates of the following features:

- Plume height
- Wind direction and speed at plume height
- Vertical temperature profile
- Atmospheric stability

- Valley flow regimes

- Footprint area (locations where ground concentrations exceed sensing threshold).

Initially, these estimates were based on routine forecasting procedures, such as Briggs plume rise equations, interpolation and extrapolation of synoptic weather patterns, patterns of diurnal temperature profile, and workbook dispersion graphs.

Two types of mobile sampling were conducted, including (1) mobile sampling traverses to identify the footprint area, SO_2 concentration profiles and temperature profiles and (2) stationary sampling to meet selected daily objectives for data. The daily objectives for selecting sampling locations included obtaining the following:

- One-hour concentration versus distance profiles for different contributions of terrain roughness and meteorological conditions. (Select stationary sampling locations which complement each other and fixed station monitors.)

- Valley to ridge concentration differences. (Select moving traverses at appropriate locations and select stationary sampling locations which complement fixed station monitors or consecutive mobile unit stationary locations.)

- For different wind directions representing different roughness fetches under otherwise similar meteorological conditions (but different sampling days), selection of sampling locations at equal distances from the power plant.

- For similar wind directions but different meteorological conditions (and different sampling days), selection of locations at equal distances from the power plant.

- Selection of traverse routes and stationary locations designed to detect the presence and magnitude of special effects, such as valley circulation, fumigation, etc., when conditions favoring such effects are forecast or observed.

During the planning operation the sampling objective was defined and tentative stationary sampling locations selected.

Based on the footprint forecast, the direction and distance to the closest sensing location was identified. A continuous display of concentrations from the SO_2 analyzer was observed in the mobile unit to identify the presence of a footprint area, to verify the suitability of the selected stationary sampling locations, and if necessary to search for more desirable locations. While within the footprint area, locations and times were logged for all significant observations. Locations were designated by means of a cylindrical coordinate system centered on the plant site. During the period from late December, 1976 through mid-March, 1977 a second mobile van (Mobile 2) was employed to search for the plume footprint area, while the Mobile 1 van was collecting stationary samples.

Each day's mobile ground sampling survey normally consisted of 4 stationary 1-hour periods during which SO_2, NO, NO_x, wind direction, wind speed, temperature and ozone were continuously measured and a particulate sample was collected for sulfate analysis. The log used to record sulfate sampling information is shown in Figure 13. SO_2 concentrations were measured continuously during mobile sampling periods within the 5 and 1/2-h sampling operation. If possible, one traverse during the period included a valley to ridge pass. The Mobile 2 van recorded only SO_2 during its 3-mo period of utilization. In the course of the mobile sampling operation, the operators were able to contact the observer in the central site to obtain new data from the fixed stations and from Pibal observations which helped locate the footprint area. A typical day's operation for a mobile ground survey is shown below:

Elapsed Time	Activities
0000 - 0100	Check system status
	Obtain and process winds aloft data
	Review and analyze data from FAX and monitoring network
0100 - 0200	Predict plume behavior
	Set up equipment
	Select sampling objectives and determine route and sampling locations
0200 - 0220	Travel to first location
0220 - 0320	On station
0320 - 0335	Travel to second location
0335 - 0435	On station (30-minute lunch break)

SULFATE SAMPLING LOG - MOBILE UNITS

Mobil Unit - Suburban ______, Helicopter ______

Grab Sampler # 1 _____ (A.C.) # 2 _____ (D.C.)

Observer _________________

Date	Filter Number	Time On	Time Off	Indicated Flow On	Indicated Flow Off

Notes:

Figure 13. Log for sulfate sampling operations.

Elapsed Time	Activities
0435 - 0455	Travel to third location (includes valley to ridge traverse)
0455 - 0555	On station
0555 - 0610	Travel to fourth location
0610 - 0710	On station
0710 - 0730	Return to central site

Figure 14 is a flow diagram showing the typical operations of the mobile unit. The Surface Mobile Sampling Log is shown in Figure 15.

Mobile Unit Calibrations--

Analyzers in the mobile unit were calibrated at the base station using the Monitor Labs Model 8500 calibration unit, which uses SO_2 and NO_2 permeation tubes and precision dilution of bottled gas with certified analysis of NO. Ozone calibration was accomplished using precisely generated quantities of ozone. A detailed description of the mobile unit calibration procedures is given in the Quality Assurance Section.

Power Plant Emission Monitoring

The emissions of SO_2, NO and exhaust gas characteristics of the two Clinch River Steam Plant stacks were monitored by obtaining the following measurements:

- Concentrations of NO and SO_2 in one stack breeching
- Temperature of exhaust gas in each stack breeching
- Mass flow rate of air into each boiler
- Net output load of each generator
- Daily laboratory analyses of the sulfur content of the coal delivered to the plant.

The concentrations of NO and SO_2 in ppm were measured by an EDC stack gas analyzer. These measurements were recorded continuously on strip charts and every 2 minutes on magnetic tape by the data acquisition system. Hourly averages of the temperature (measured at stack base), the air mass flow rate (measured in boiler intake), and the net output load from each generator were furnished by the plant each week. Daily

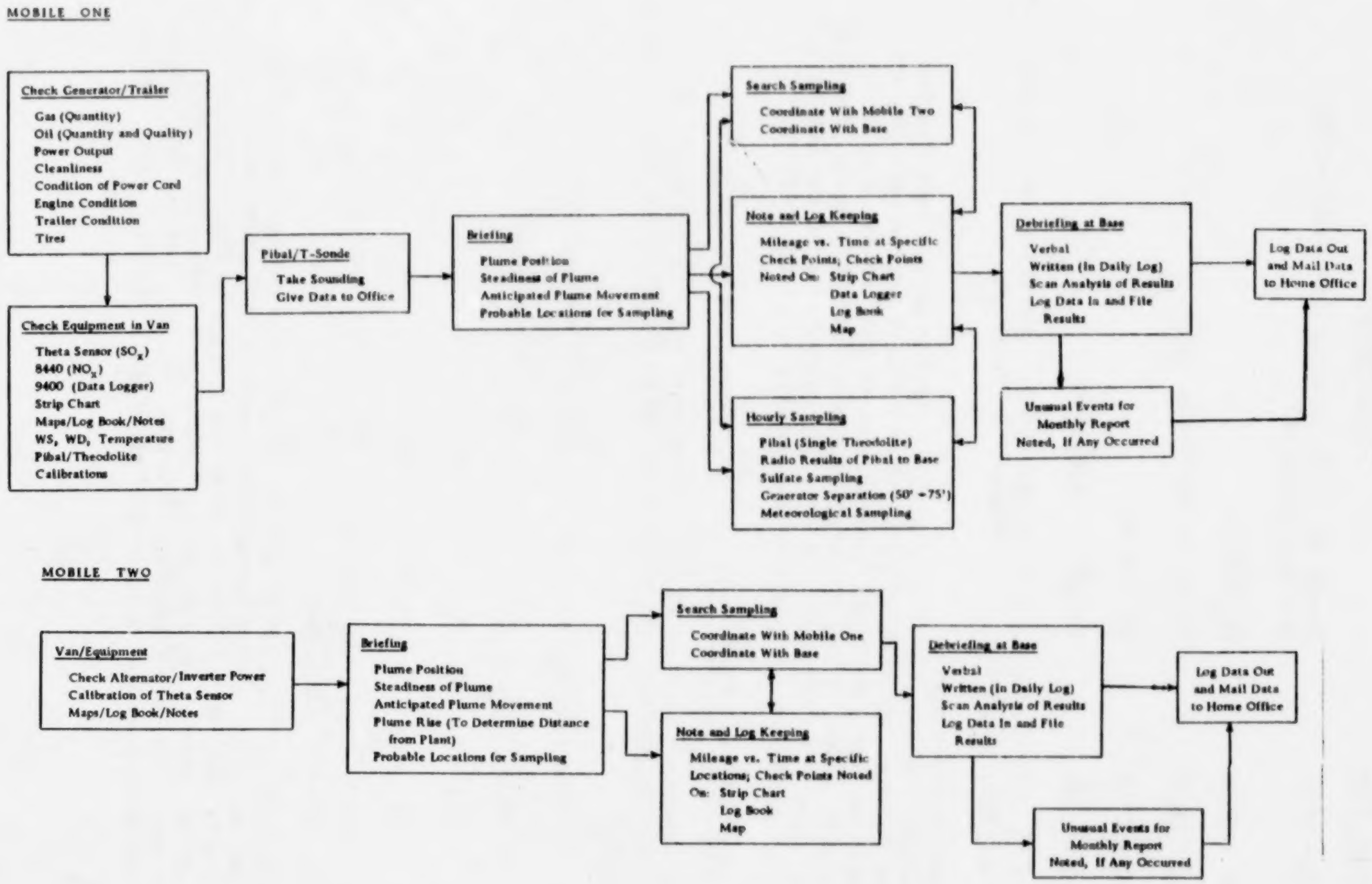

MOBILE ONE
Check Generator/Trailer
Gas (Quantity)
Oil (Quantity and Quality)
Power Output
Cleanliness
Condition of Power Cord
Engine Condition
Trailer Condition
Tires
Check Equipment in Van
Theta Sensor (SO$_x$)
8440 (NO$_x$)
9400 (Data Logger)
Strip Chart
Maps/Log Book/Notes
WS, WD, Temperature
Pibal/Theodolite
Calibrations
Pibal/T-Sonde
Take Sounding
Give Data to Office
Briefing
Plume Position
Steadiness of Plume
Anticipated Plume Movement
Probable Locations for Sampling
Search Sampling
Coordinate With Mobile Two
Coordinate With Base
Note and Log Keeping
Mileage vs. Time at Specific
Check Points; Check Points
Noted On: Strip Chart
Data Logger
Log Book
Map
Hourly Sampling
Pibal (Single Theodolite)
Radio Results of Pibal to Base
Sulfate Sampling
Generator Separation (50' – 75')
Meteorological Sampling
Debriefing at Base
Verbal
Written (In Daily Log)
Scan Analysis of Results
Log Data In and File
Results
Unusual Events for
Monthly Report
Noted, If Any Occurred
Log Data Out
and Mail Data
to Home Office
MOBILE TWO
Van/Equipment
Check Alternator/Inverter Power
Calibration of Theta Sensor
Maps/Log Book/Notes
Briefing
Plume Position
Steadiness of Plume
Anticipated Plume Movement
Plume Rise (To Determine Distance
from Plant)
Probable Locations for Sampling
Search Sampling
Coordinate With Mobile One
Coordinate With Base
Note and Log Keeping
Mileage vs. Time at Specific
Locations; Check Points Noted
On: Strip Chart
Log Book
Map
Debriefing at Base
Verbal
Written (In Daily Log)
Scan Analysis of Results
Log Data In and File
Results
Unusual Events for
Monthly Report
Noted, If Any Occurred
Log Data Out
and Mail Data
to Home Office

Figure 14. Decision process for operating mobile vans.

Surface Mobile Sampling Log page 1 of ___

Date: Sampling Time: __________ to __________

Mobile Unit #:

Observer:

General Weather Conditions:

Estimates of Cloud

	Low	Middle	High
Height (ft.)			
Amount (tenths)			

Pibal Wind

	219-420m	420-622m	622-813m
Wind Direction			
Wind Speed			

Observed Plume Direction (near stack):

Do vapor plumes from cooling towers intersect stack plumes? Yes____, No____

Weather Phenomena (e.g., fog, rain, snow, smoke, etc.):

(continued)

Figure 15. Log for ground mobile sampling

Surface Mobile Sampling Log continued

Page 2 of ___

Sampling Route (in general):

Map Event Mark	Time	Speedometer Reading	Remarks

Figure 15. (continued)

laboratory measures of the sulfur content of the coal shipments received were also furnished by the plant. The plant also furnished hourly averages of the makeup water used in the cooling system which was a measure of the water vapor emitted from the cooling towers.

Exhaust gases from the third boiler were released from Stack No. 2 in which the exhaust gas monitor was located. Calculated emission rates of SO_2 and NO were prepared for each of the two stacks using the collected data and the methods described in Section 5. Both measured and calculated values were available for Stack No. 2 which services one boiler.

There is one other significant source of SO_2 or NO_x emissions in the vicinity of the plant and that is a coal preparation plant which is 3 km north-northeast of the power plant (see Figure 1). This plant when operating at its maximum capacity 24-hours a day could burn 60 tons of coal per day, which is 1 percent of the normal coal consumption rate at the power plant. The only monitor on which it appears the coal plant emissions had a significant effect was the Tower site, 1 km away. When the wind was west-northwest, it blew directly from the coal preparation plant to the Tower site, and spikes of 25 to 30 ppb in SO_2 readings were recorded on a strip chart. These spikes were easily distinguished from the effects from the power plant which occurred with a southwest wind direction.

Stack temperatures for both stacks 1 and 2 were measured by thermocouples placed in the breeching about one-third of the way from the precipitator to stack inlet.

Pressure was measured in the control room. A mercury column barometer was used and was uncorrected, so the pressure measured was the atmospheric pressure above the power plant control room.

Airborne Mobile Sampling

A Bell Jet Ranger helicopter was used to fly a set of air quality analyzers during two intensive study periods. Approximately 75 hours of flight time were logged during the intensive study periods.

Air quality measurements of SO_2, NO, NO_2, NO_x and O_3 were continuously scanned and recorded on a digital cassette tape unit which also recorded data and time at the beginning of each scan. During the second study period, temperature, relative humidity, altimeter and indicated air speed were recorded on cassette tape also. Three strip chart recorders were used to display the concentration trace of SO_2, NO and O_3. An observer and a technician rode with the pilot during all flights to operate the instruments, make necessary notes on time and location and to direct the sampling operation. Communications between the helicopter crew and other GEOMET personnel conducting the ground operation were maintained using two-way business band radios.

The objectives of the airborne monitoring work were to obtain enough data to describe the location and/or dimensions of the power plant plume under a variety of meteorological conditions. The flight procedure to obtain a cross section of the plume at various distances downwind along the plume path is illustrated in Figure 16.

During the first sampling period more emphasis was made on determining plume location and the behavior of the plume with respect to topographical features. During the second sampling period emphasis was primarily on plume dimensions at several downwind distances within 10 km of the plant.

Event marks were made upon entering or exiting the plume as determined by the technician watching the strip chart recorder. A log of altimeter, air speed and heading values was obtained by reading from the panel in the cockpit whenever an event was recorded. During the first sampling period aircraft locations were marked on a 1:24000 scale topographic map whenever an event was recorded. In the second sampling period ground check points were selected which were outside of both sides of the plume. The helicopter flew between these check points at different altitudes. On each traverse the time that the aircraft passed over the checkpoint was noted and assigned an event number.

The observer rode in the front seat beside the pilot and performed the following functions:

- Manually record position, time, event, and pertinent notes - maintain log of the sample period (Figure 17)
- Communicate with base station regarding aircraft activities, plume location, etc.
- Communicate with pilot regarding sampling strategy, location, etc.

The technician rode in the rear seat with the instruments and performed the following functions:

- Turn on and off analyzers and recorders
- Make event marks on strip charts and data logger
- Observe when entering or leaving plume boundaries and inform observer when each event occurs so that it may be entered in the written log
- Make necessary adjustments to instruments.

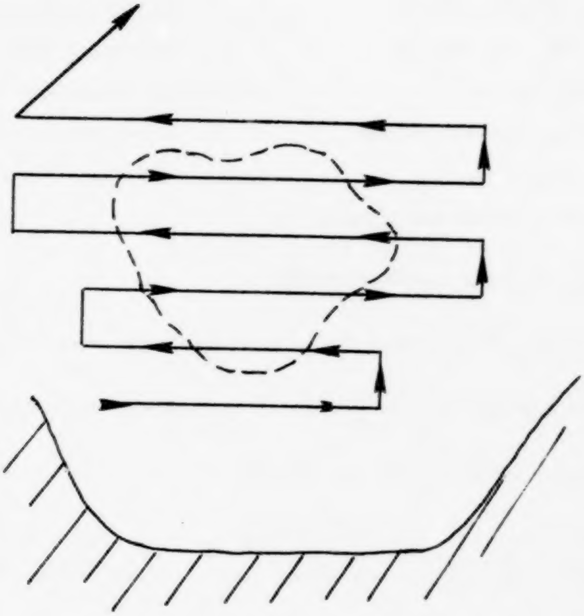


Figure 16. Representative helicopter flight path at fixed distance from the power plant.

Page 1 of __

HELICOPTER SAMPLING LOG

Observer:

Date:

Sampling Time: ______ to ______

Equipment in Operation:

SO_2 Analyzer (Sign X)	( )	M8 Package Airspeed	( )
SO_2 Analyzer (Theta)	( )	M8 Package Altitude	( )
NO, NO_2, NO_x Analyzer	( )	M8 Package Temperature	( )
Ozone Analyzer	( )	M8 Package R.H.	( )
* Particulate Grab Sampler	( )	DL 640 and Tape Recorder	( )
M8 Package Heading	( )	Strip Chart Recorder	( )

General Weather Condition:

Measured Plume Elevation (m)(MSL):

Wind Direction at Plume Height (from Helicopter Plume Intercepts):

Wind Speed at Plume Height (mps)(from Pibals or State Other Source):

General Sampling Direction and Ranges:

Position Ident.	Time	Direction and Distance from Plant (Km)	Observations & Remarks (Landmarks, Comments, etc.)

* Particulate grab sampler not used in helicopter sampling program.

Figure 17. Log of helicopter sampling.

AIRBORNE SAMPLING LOG

DATE ________ OBSERVER

PAGE ________ TECHNICIAN

Time		Event	Heading	Airspeed	Altitude	SO_2	NO	O_3	Notes
Hr/Min	Sec	#	degrees		ft	PPM	PPM	PPM	

Figure 17. (cont'd)

Zero and calibration tests were performed on the Theta Sensor, NO, NO$_x$ analyzer and ozone analyzer before taking off each time a sampling run was to be made. During the second intensive period zero and span data were recorded after each flight. The analyzers were left running each night to reduce warm-up time and to reduce drift which might be enhanced by turning the instruments on and off.

Approximately 30 min before take-off, the helicopter observer called the power plant base station to get an update on the plume projection and its calculated height. A sampling procedure was discussed and decisions made as to whether or not they would start off by plume chasing or by getting plume characteristics.

Upper Air Soundings

To completely characterize the meteorological conditions, upper air temperature and wind data must be known in the vicinity of the Clinch River plant. The National Weather Service network of soundings taken around the United States does not include a station near the southwestern Virginia area. The closest station at Huntington, West Virginia, is about 150 km away. Temperature and wind soundings taken at the Clinch River site give results most representative of the surrounding region.

On a daily basis Pilot Balloons were launched at specific times to characterize various meteorological situations. Temperature soundings were obtained during some periods using the Contel Corporation "MiniSonde" in conjunction with a Pibal. Temperature data was transmitted back to the ground by a small radio contained in the Mini-Sonde. The signal was translated into continuous trace of temperature recorded on a strip chart.

Pibals and Pibal-T Sondes were tracked using two theodolites beginning on June 2, 1976. Although double theodolite procedures predominated, single theodolite measurements were used if a theodolite station failed during a particular sounding.

A diagram of the sounding location is found in Figure 18. The baseline used was selected at the time of each sounding to use a baseline that was not parallel to the direction of flight in order to increase the resolution of balloon positions determined by the two theodolite observations.

The number of soundings per day changed from one a day, at the beginning of the project to three or four a day at the end. T-Sondes were not incorporated until late 1976 with at least 12 per week being flown at the end of the project.

A precision machined 30g balloon filling device was used to fill the pibals. Helium was added until a 30g weight just lifted off the ground. When a T-sonde was attached to a pibal being tracked by a single theodolite, additional helium was added to the pibal to compensate for the extra weight of the T-sonde, thereby maintaining the proper buoyancy.

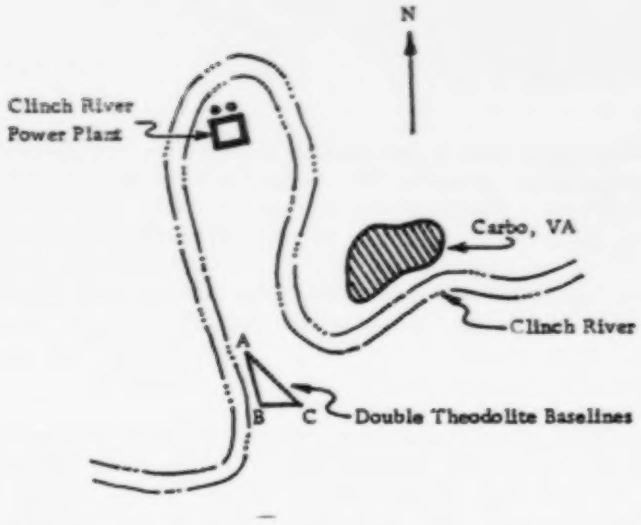

N
Clinch River
Power Plant
Carbo, VA
Clinch River
A
B
C
Double Theodolite Baselines

Figure 18a. Diagram showing location of double theodolite baselines relative to the Clinch River Power Plant near Carbo, VA.

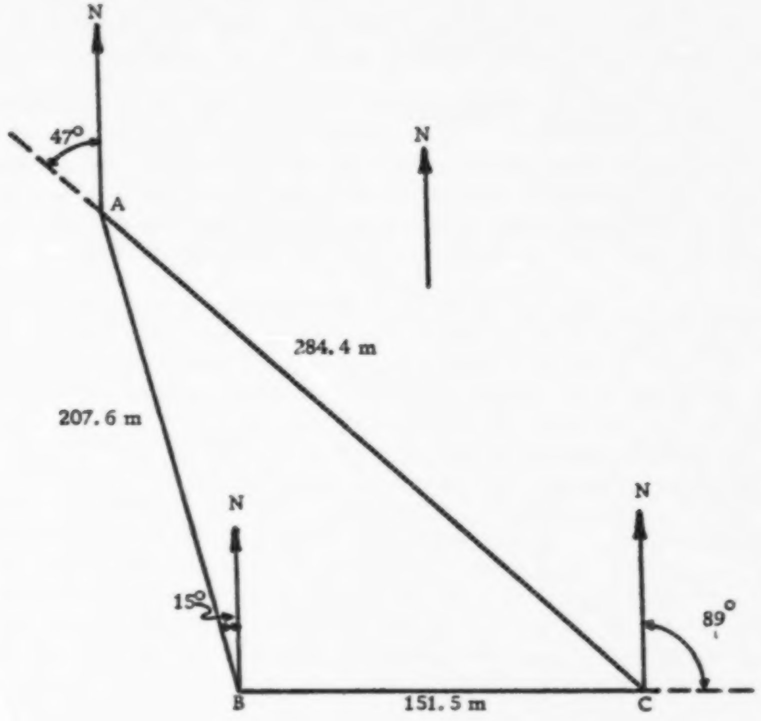

N
47°
A
N
284.4 m
207.6 m
N
N
15°
89°
B
151.5 m
C

Figure 18b. Dimensions and angular arrangement of double theodolite baselines located just south of the Clinch River Power Plant near Carbo, VA.

All azimuth, elevation and temperature data were introduced into a Texas Instruments SR-52 calculator program for reduction in the field. This method gave wind speed, direction, temperature versus height, and vertical wind information based on trigonometric reduction of two azimuth angles and one elevation. Subsequent processing of the data with a PDP 11-70 computer system determined position based on two azimuth and two elevation angles and the most probable location of the balloon based on the angular inputs.

Plume Photography

Associated with the intensive study period of July 18 through July 28, 1977 was a program of intensive plume photography. Three locations were chosen within a few km of the plant that had unobstructed views of the plant smokestacks. Site A was located on a bearing of 108° from the plant at a distance of 6 km, Site B was located on a bearing of 165° from the plant at a distance of 4 km, and Site C was located on a bearing of 290° from the plant at a distance of 3 km (see Figure 19).

The sites were chosen so that regardless of the wind direction at least one site would provide a good angle of view of the plume as it exited the stacks and traveled downwind. However, due to the synoptic conditions during the intensive sampling period, only sites A and B were actually utilized.

The photographic program consisted of taking sequential photographs of the power plant plume while the Unit 1 electrostatic precipitators were reduced.* Having the precipitators reduced allowed for better visual observations of the plume by both the photographic and airborne sampling teams. On 2 days of the program, the Unit 3 precipitators (serving the second stack) were also reduced in an effort to see at what point downwind the two plumes merged.

The photographic team used a Nikon F 35 mm camera with motor drive and interchangeable 200 and 400 mm lenses. The camera was mounted on a tripod and aimed to take in as much of the power plant plume, while still including the stacks, as the angle of view would allow. The photographs were taken at 2-minute intervals using Tri-X 400 ASA Black and White film. Very clear plume photographs were obtained by using a combination of red and polarizing filters to cut through local haze. Detailed records were kept to accurately log the time of each photograph as well as any significant meteorological phenomenon that may have occurred during the day. The photographic team was kept informed of any possible wind shift trends by the base station personnel via the two-way radio. When large shifts in wind direction indicated that one of the other photographic sites would provide a better view of the plume, the photographic team was able to move their equipment from their present location and set it up at the other site with only a minimum loss in photographic time.

---

* Turning down of the precipitators was coordinated with and reported to state air pollution control authorities.

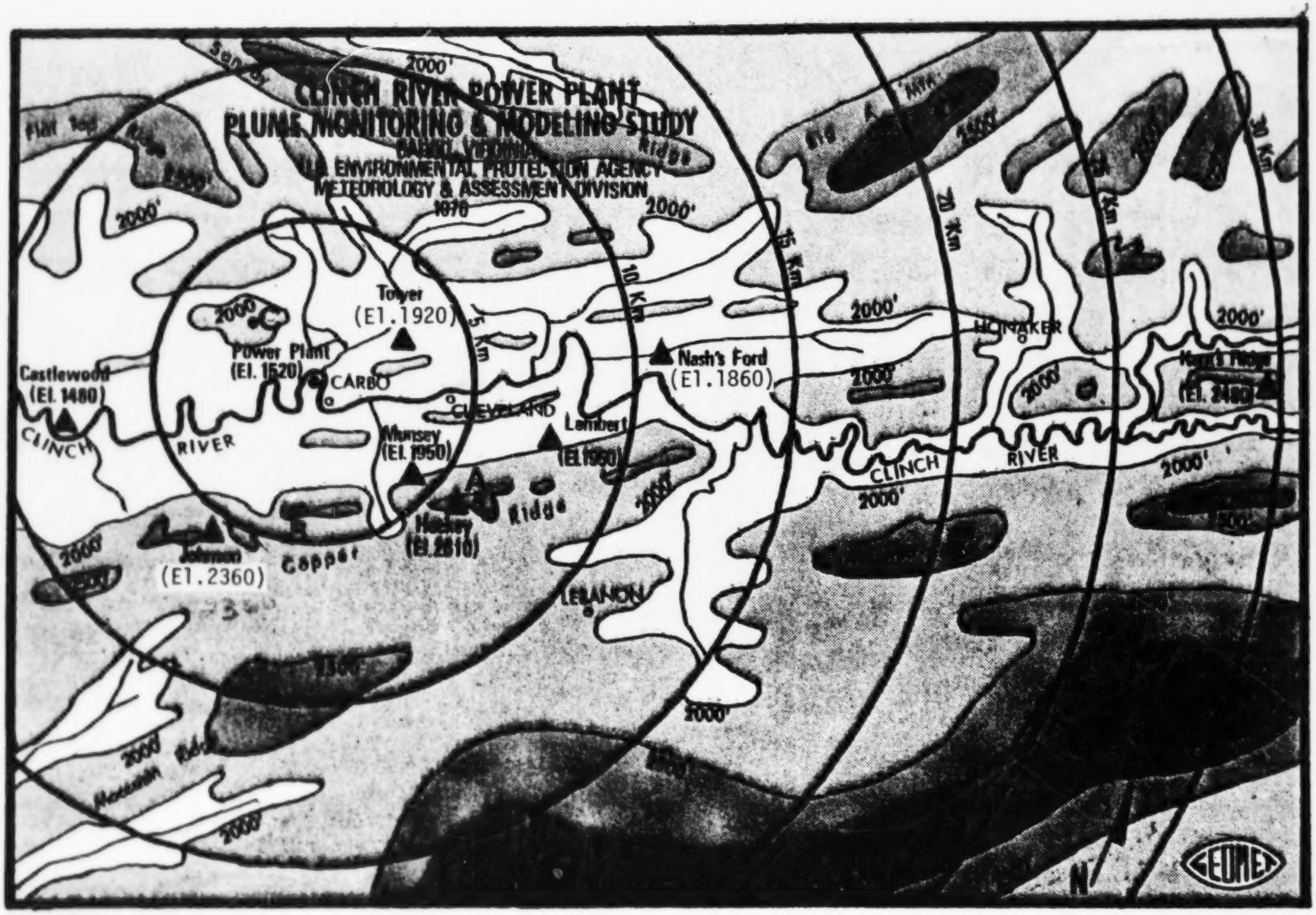

CLINCH RIVER POWER PLANT
PLUME MONITORING & MODELING STUDY
CARBO, VIRGINIA
U.S. ENVIRONMENTAL PROTECTION AGENCY
METEOROLOGY & ASSESSMENT DIVISION
Sandy
Flat Top Ridge
Big A Mtn
Ridge
2000'
1876
5 Km
10 Km
15 Km
20 Km
25 Km
30 Km
Tower
(El.1920)
Power Plant
(El. 1520)
CARBO
Castlewood
(El. 1480)
CLINCH
RIVER
CLEVELAND
Munsey
(El. 1950)
Lambert
(El.1950)
Nash's Ford
(El.1860)
Hackey
(El.2810)
Ridge
Copper
Johnson
(El.2360)
LEBANON
HONAKER
Hart's Ridge
(El. 2480)
CLINCH RIVER
Moccasin Ridge
N
GEOMET

Figure 19. Location of plume photography sites (designated A, B, and C).

In 5 days of picture taking, approximately 700 plume images were obtained. Some examples of these are presented in Figure 20. The objective of the photographic program was to obtain plume height estimates based on each photographic image and to prepare a data file containing observation identification (date, time, location), location of "maximum" plume height, plume width, and associated meteorological and plant operational data for further analysis. Comparisons could also be made between the visually measured plume height and the height of maximum pollutant concentrations as determined by the airborne sampling program.

QUALITY ASSURANCE

Record Keeping

A comprehensive set of records was maintained in order to permit detailed tracing of the data collection process when future reviews are made of the Clinch River data. Records of types of data, where collected, when collected, how collected, by whom, how and when the data was transported and where it was sent are all items that have been accounted for.

To acquaint the reader with the supplemental information that is available, a brief explanation of the individual log sheets follows.

Any data that left the field office was properly logged out so that there was an identifiable record of the particular data sent, the date it left, where it was headed and the mode of transportation. There was a complete log of every item of datum that was collected in the field. Whenever a strip chart was removed from a field station and transported to the base station, this was logged in the station manual as well as the office log. Whenever that segment of data was then sent either to Gaithersburg or to a particular laboratory for analysis, a complete log was available as to the whereabouts and status of that data.

In the following subsections, as each item of data is discussed, the various forms and procedures for transfering the data from one location to the next will be included where appropriate.

A Station Check List (Figures 21 and 22) was completed during each visit to a fixed monitoring site and provided an account of the status of all equipment at a station. The procedure for completing this form was described under BASE STATION OPERATING PROCEDURES.

Any visit to a station was also logged in the station log book. If any work was done or changes were made, the procedure was carefully outlined in the log.

To determine the SO_2 and NO_x emissions and exhaust gas characteristics of the plant, operating records were obtained weekly from the Clinch River Plant records. Sample data are presented in Figures 23, 24, and 25. Gross generator load, boiler intake air flow rate, and stack gas inlet temperature were obtained from these data sheets. Coal percent sulfur data was obtained from records kept by the power company's chemistry laboratory.

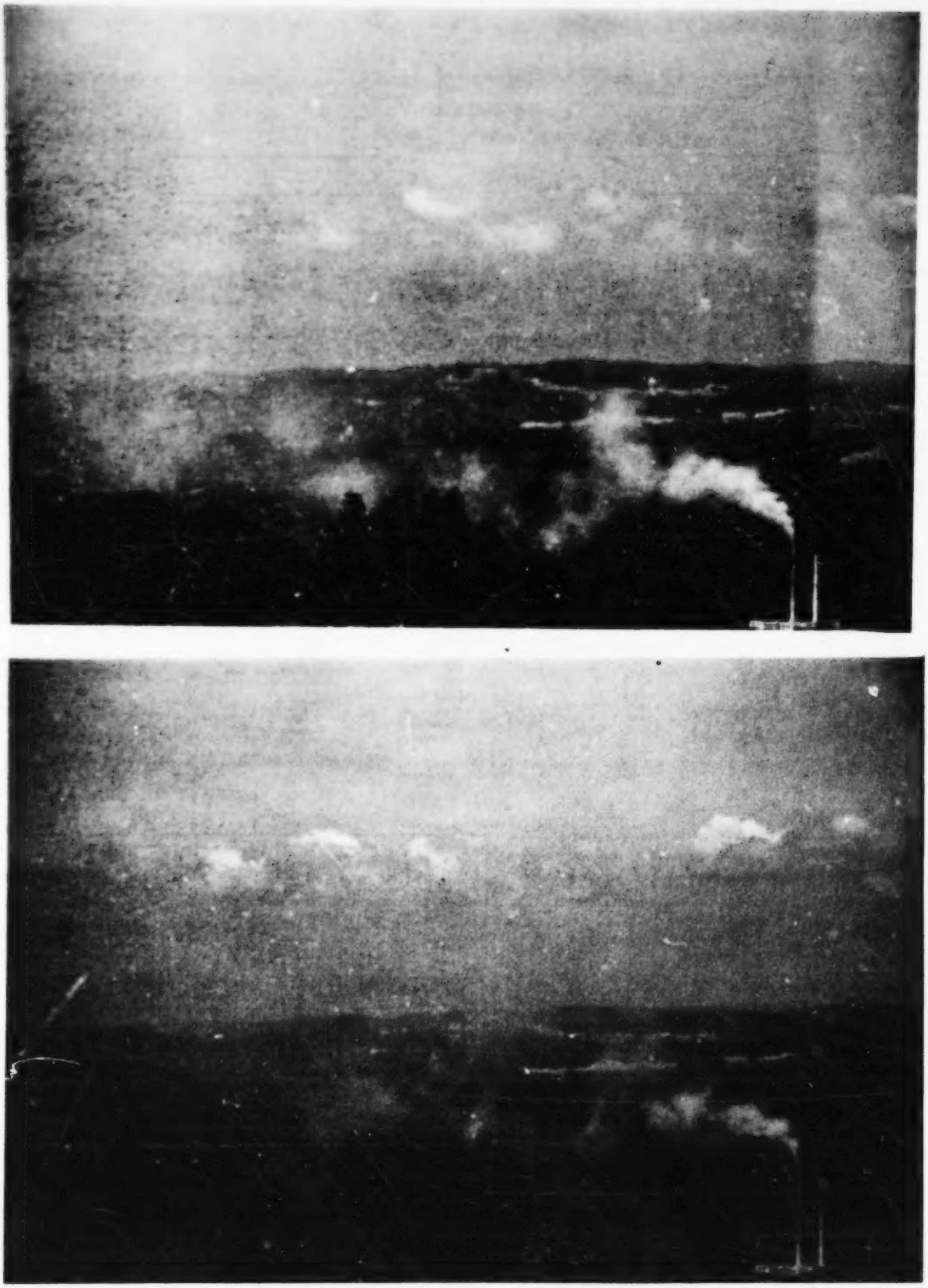


Figure 20. Sample plume photos.

CLINCH RIVER PLUME STUDY

STATION CHECK LIST

Date ____________________ Location ____________________

Time ____________________ EST Observer ____________________

OUTSIDE

Trailer Appearance

Wind Systems: Cups Rotating ☐

Vane(s) in Good Shape ☐

Temperature Asperators Working ☐

Hi-Vol Appears to be OK? ☐

Tower General Condition: Ground Cable ☐

Sensor Cables ☐

Booms OK ☐

Trailer Locked? ☐

INSIDE

Clock Time Check OK ____ Fast ____ Slow ____ Hr ____ Min ____

General Appearance Inside Trailer: Inlet Sink Trap Clean ☐

Manifold Clean ☐

Inlet Lines Connected ☐

Exhaust Lines to Exhaust Fan ☐

Both Fans Running ☐

SO_2 - 8450

Mark with X all lights that are on and all switches that are in an In position. Mark with F all flashing lights.

Write in H_2 Flow Rate ____________________

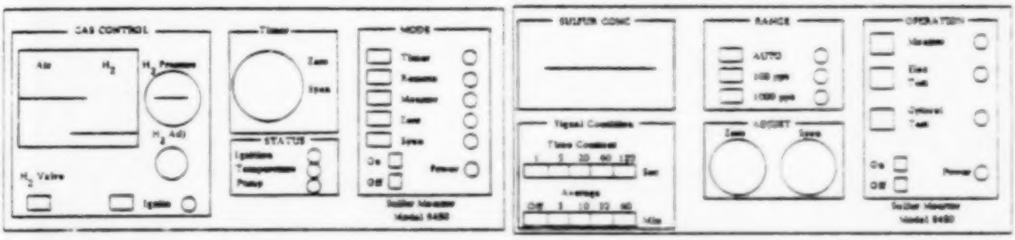
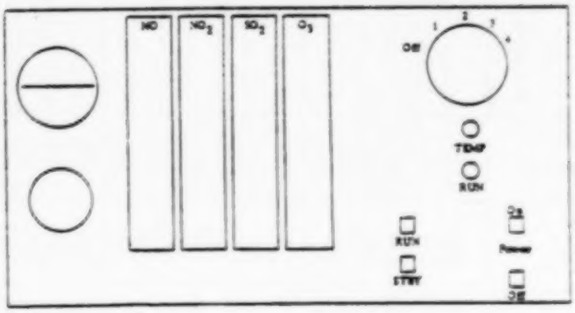

GAS CONTROL
Air
H2
H2 Pressure
H2 Adj
H2 Valve
Ignite
Timer
Zero
Span
STATUS
Ignition
Temperature
Pump
MODE
Timer
Monitor
Zero
Span
On
Off
Power
Sulfur Monitor
Model 8450
SULFUR CONC
Signal Conditions
Time Constant
1 3 20 60 120
Sec
Average
Off 1 10 30 60
Min
RANGE
AUTO
100 ppm
1000 ppm
ADJUST
Zero
Span
OPERATION
Monitor
Elec Test
Optional Test
On
Off
Power
Sulfur Monitor
Model 8450

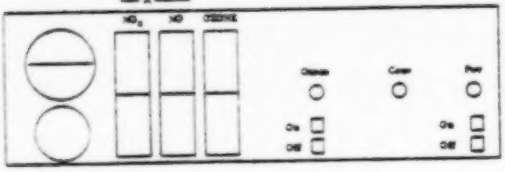
Figure 21. Station check list, page one.

Calibrator 8500

Oven Temperature ____ °C

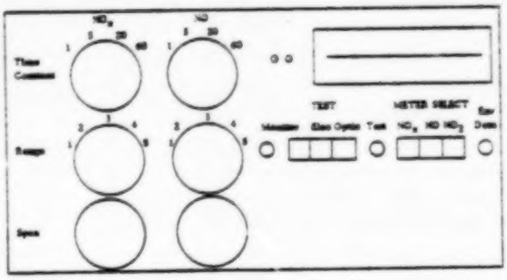

NO
NO_2
SO_2
O_3
Off
1
2
3
4
TEMP
RUN
RUN
STBY
On
Power
Off

NO_x 8440

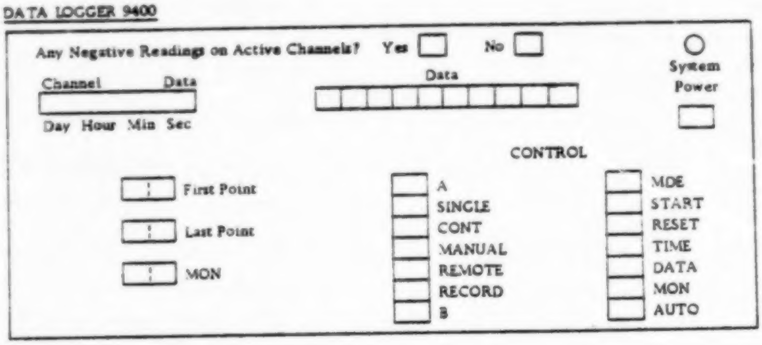

NO_x
NO
OZONE
On
Off
On
Off

% Drierite gone ________

Zero/span/monitor switch (on back) in monitor mode? ______


NO_x
NO
Time Constant
1
5
20
60
Range
1
2
3
4
5
Span
TEST
METER SELECT
Monitor
Elec Optic
Test
NO_x
NO
NO_2

DATA LOGGER 9400


Any Negative Readings on Active Channels? Yes ☐ No ☐

System Power
Channel
Data
Day Hour Min Sec
Data
CONTROL
First Point
Last Point
MON
A
SINGLE
CONT
MANUAL
REMOTE
RECORD
B
MDE
START
RESET
TIME
DATA
MON
AUTO

CHART RECORDER - Mark Date/Time Sticker

			How Many Tanks
H_2 Tanks -	Line Pressure ________psi	Tank Pressure ________psi	______
NO Tanks -	Line Pressure ________psi	Tank Pressure ________psi	______

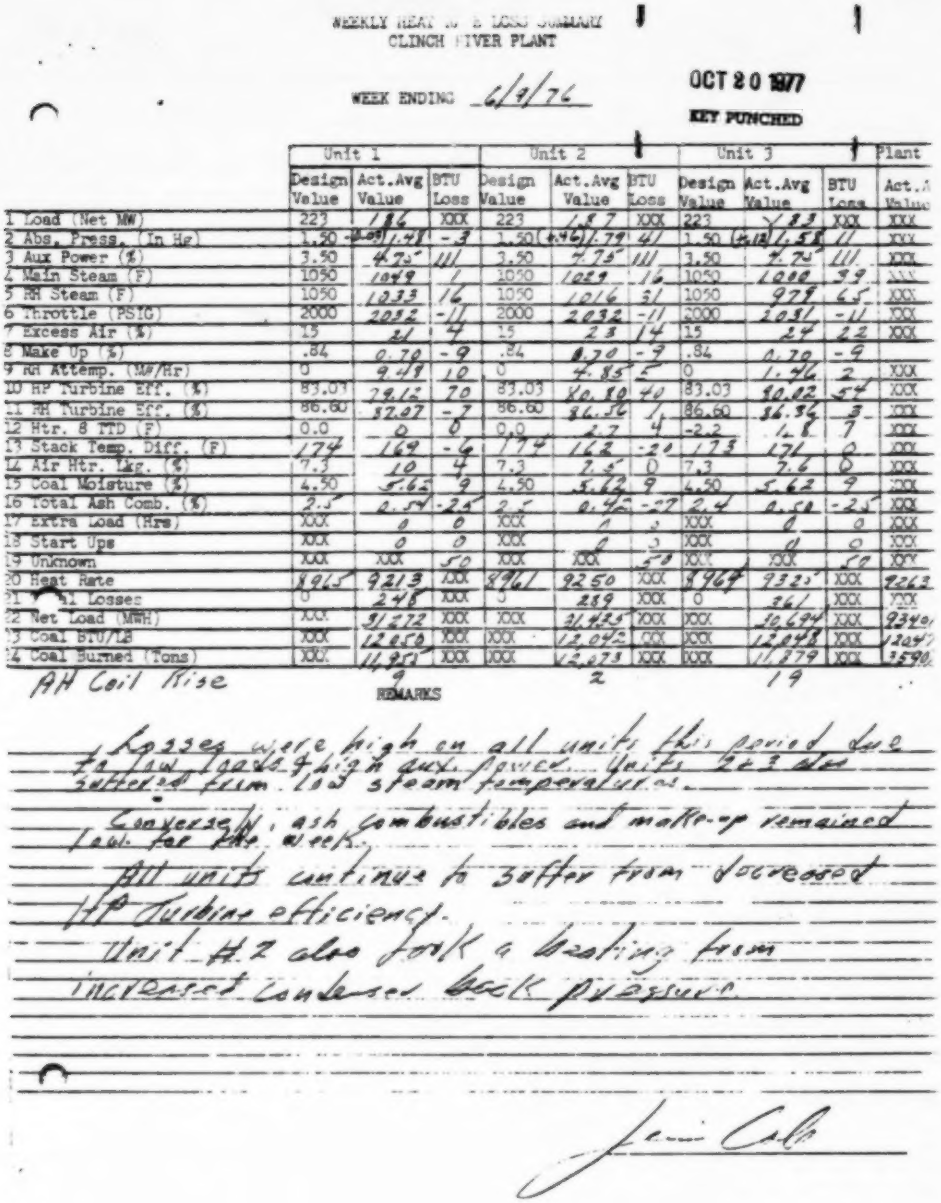
Figure 22. Station check list, page two.

Date: July 17, 1977

Hourly Control Room Heating for Heat Rate Loss Monitoring

Time	Main Steam °F Avg	R'HT Steam °F Avg	R'HT ATT. #/Hr Total	THR Press PSI	Gross Load MW	Exc. Air % Avg	Air Htr Gas Out-Air In °F	BFPT CV Lift Inches	Heat Rate Loss BTU/MKW Total	Circ Water °F In	Circ Water °F Out	Cond. Vac "HG	Bar. Press "HG	Stack Inlet Temp °F	Boilder Air Flow M#/Hr	Remarks
0100	1025	985	0	2050	150	25	162	2.88	75	74	92	27.13	28.70	244	1220	
0200	1050	1025	0	2050	180	21	169	2.75	24	74	92	27.01	28.69	241	1400	
0300	1050	1020	0	2050	152	25	161	2.83	28	75	89	27.08	28.69	245	1225	
0400	1050	1012	0	2050	149	25	161	2.90	35	75	80	27.17	28.69	245	1210	
0500	1050	1012	0	2050	149	25	162	2.84	35	74	86	27.21	28.70	241	1210	
0600	1045	993	0	1950	132	35	157	2.75	106	74	85	27.32	28.70	239	1210	
0700	1045	995	0	1950	132	30	155	2.80	80	75	84	27.27	28.70	230	1110	
0800	1050	995	0	1950	132	30	155	2.75	79	76	85	27.26	28.71	235	1110	
0900	1035	980	0	1950	132	30	155	2.90	102	79	89	27.09	28.71	235	1110	
1000	1040	1005	0	2050	165	20	155	2.90	45	81	93	26.85	28.70	240	1280	
1100	1035	1035	0	2050	218	16	178	3.35	22	84	102	26.25	28.69	257	1620	
1200	1040	1050	0	2050	218	16	178	3.04	7	84	102	26.18	28.67	268	1620	
1300	1040	1040	0	2050	216	15	178	3.15	17	84	102	26.28	28.67	272	1600	
1400	1045	1045	0	2050	214	18	178	2.95	7	83	101	26.28	28.64	272	1570	
1500	1050	1050	6	2050	215	19	180	2.75	7	81	98	26.35	28.64	274	1540	
1600	1050	1040	0	2050	207	20	180	2.90	35	81	98	26.36	28.64	274	1530	
1700	1050	1040	0	2050	206	19	181	2.90	35	82	99	26.28	28.65	276	1520	
1800	1050	1040	0	2050	206	19	180	2.90	35	84	100	26.25	28.63	278	1520	
1900	1040	1010	0	1050	185	20	175	2.85	47	85	97	26.44	28.65	274	1350	
2000	1045	1010	0	2050	177	20	175	2.80	41	80	97	26.47	28.66	265	1340	
2100	1040	1015	0	2050	183	19	180	2.80	35	83	97	26.47	28.67	265	1390	
2200	1045	1010	0	2050	170	22	170	2.85	37	81	93	26.73	28.67	263	1220	
2300	1050	1005	0	1950	134	34	162	2.83	76	80	92	27.00	28.69	255	1120	
2400	1050	1005	0	1950	134	34	161	2.68	76	79	90	27.08	28.70	250	1125	

Figure 23. Sample operating record - hourly heat rate loss monitoring.



WEEKLY HEAT RATE LOSS SUMMARY
CLINCH RIVER PLANT

WEEK ENDING 6/9/76

OCT 20 1977

KEY PUNCHED

	Unit 1			Unit 2			Unit 3			Plant
	Design Value	Act.Avg Value	BTU Loss	Design Value	Act.Avg Value	BTU Loss	Design Value	Act.Avg Value	BTU Loss	Act.A Valu
1 Load (Net MW)	223	186	XXX	223	187	XXX	223	183	XXX	XXX
2 Abs. Press. (In Hg)	1.50	(-.09) 1.48	-3	1.50	(+.46) 1.79	41	1.50	(+.12) 1.58	11	XXX
3 Aux Power (%)	3.50	4.75	111	3.50	4.75	111	3.50	4.75	111	XXX
4 Main Steam (F)	1050	1049	1	1050	1029	16	1050	1000	39	XXX
5 RH Steam (F)	1050	1033	16	1050	1016	31	1050	979	65	XXX
6 Throttle (PSIG)	2000	2032	-11	2000	2032	-11	2000	2031	-11	XXX
7 Excess Air (%)	15	21	4	15	23	14	15	24	22	XXX
8 Make Up (%)	.84	0.70	-9	.84	0.70	-9	.84	0.70	-9	
9 RH Attemp. (M#/Hr)	0	9.48	10	0	4.85	5	0	1.46	2	XXX
10 HP Turbine Eff. (%)	83.03	79.12	70	83.03	80.80	40	83.03	80.02	54	XXX
11 RH Turbine Eff. (%)	86.60	87.07	-7	86.60	86.56	1	86.60	86.36	3	XXX
12 Htr. 8 TTD (F)	0.0	0	0	0.0	2.7	4	-2.2	1.8	7	XXX
13 Stack Temp. Diff. (F)	174	169	-6	174	162	-20	173	171	0	XXX
14 Air Htr. Lkg. (%)	7.3	10	4	7.3	7.5	0	7.3	7.6	0	XXX
15 Coal Moisture (%)	4.50	5.62	9	4.50	5.62	9	4.50	5.62	9	XXX
16 Total Ash Comb. (%)	2.5	0.54	-25	2.5	0.42	-27	2.4	0.50	-25	XXX
17 Extra Load (Hrs)	XXX	0	0	XXX	0	0	XXX	0	0	XXX
18 Start Ups	XXX	0	0	XXX	0	0	XXX	0	0	XXX
19 Unknown	XXX	XXX	50	XXX	XXX	50	XXX	XXX	50	XXX
20 Heat Rate	8965	9213	XXX	8961	9250	XXX	8964	9325	XXX	9263
21 Total Losses	0	248	XXX	0	289	XXX	0	361	XXX	XXX
22 Net Load (MWH)	XXX	31,272	XXX	XXX	31,435	XXX	XXX	30,694	XXX	9340
23 Coal BTU/LB	XXX	12,050	XXX	XXX	12,042	XXX	XXX	12,048	XXX	1204
24 Coal Burned (Tons)	XXX	11,951	XXX	XXX	12,073	XXX	XXX	11,879	XXX	3590
AH Coil Rise		9			2			19		

REMARKS

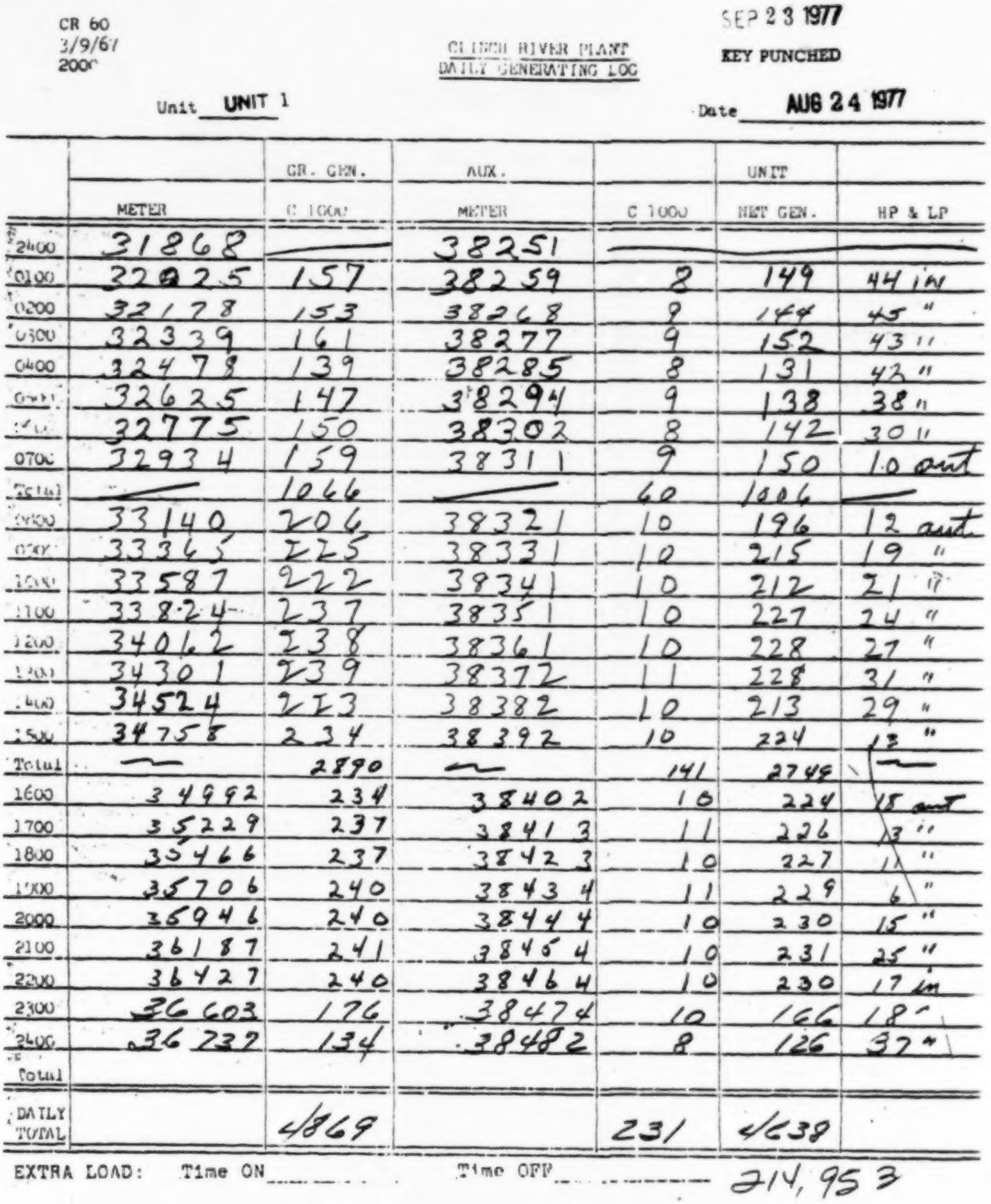
Losses were high on all units this period due to low loads & high aux. power. Units 2 & 3 also suffered from low steam temperatures.

Conversely, ash combustibles and make-up remained low for the week.

All units continue to suffer from decreased HP turbine efficiency.

Unit #2 also took a beating from increased condenser back pressure.

Figure 24. Sample operating record - weekly heat rate loss summary.



CR 60
3/9/67
2000

CLINCH RIVER PLANT
DAILY GENERATING LOG

SEP 23 1977
KEY PUNCHED

Unit UNIT 1

Date AUG 24 1977

		GR. GEN.	AUX.		UNIT	
	METER	C 1000	METER	C 1000	NET GEN.	HP & LP
2400	31868		38251			
0100	32025	157	38259	8	149	44 in
0200	32178	153	38268	9	144	45 "
0300	32339	161	38277	9	152	43 "
0400	32478	139	38285	8	131	42 "
0500	32625	147	38294	9	138	38 "
0600	32775	150	38302	8	142	30 "
0700	32934	159	38311	9	150	1.0 out
Total		1066		60	1006	
0800	33140	206	38321	10	196	12 out
0900	33365	225	38331	10	215	19 "
1000	33587	222	38341	10	212	21 "
1100	33824	237	38351	10	227	24 "
1200	34062	238	38361	10	228	27 "
1300	34301	239	38372	11	228	31 "
1400	34524	223	38382	10	213	29 "
1500	34758	234	38392	10	224	13 "
Total		2890		141	2749	
1600	34992	234	38402	10	224	15 out
1700	35229	237	38413	11	226	13 "
1800	35466	237	38423	10	227	11 "
1900	35706	240	38434	11	229	6 "
2000	35946	240	38444	10	230	15 "
2100	36187	241	38454	10	231	25 "
2200	36427	240	38464	10	230	17 in
2300	36603	176	38474	10	166	18 "
2400	36737	134	38482	8	126	37 "
Total						
DAILY TOTAL		4869		231	4638	

EXTRA LOAD: Time ON______ Time OFF______ 214,953

Figure 25. Sample operating record - daily generating log.

Each day of the week a Daily Project Report was completed to record all events of that day. This form was completed at a time when all staff members were together to discuss the events of the day and is illustrated in Figure 10.

Mobile Sampling Logs provided records of mobile data which were very important in putting the data into the proper context. Vehicle location, type of sampling (mobile cross-plume or stationary sample), local terrain features and significant events were recorded for the analysis of mobile data. Range settings and output voltages were recorded for each instrument. An identification label was affixed to each strip chart or tape to properly identify the data.

During the airborne sampling an extremely detailed series of notes was kept to properly identify the helicopter location. Types of equipment, ranges and outputs were also recorded to reduce the data to a usable form. Channel input to the data logger was recorded at the beginning of each sampling period to properly identify which instruments were writing on each channel. This information was recorded for each helicopter flight on the Helicopter Sampling Log and Airborne Sampling Log shown in Figure 17.

Regular soundings of wind speed and direction were recorded on the Double Theodolite Form (Figure 26). Temperature data obtained by suspending a T-Sonde from the Pibal were recorded on the T-Sonde Data Report (Figure 27). The Pibal data were initially recorded by voice on a cassette tape recorder while the temperature sounding was plotted on a strip chart. Reduction of this data was performed in the field and recorded on the appropriate Pibal or T-Sonde forms.

Numerous sulfate samples were collected during the Clinch River study. To properly identify the conditions under which each sample was collected, the form shown in Figure 28 was completed. Information as to when and where a sample was collected was important for proper analysis of sulfate samples. Records of mobile sulfate data were recorded using the form shown in Figure 29.

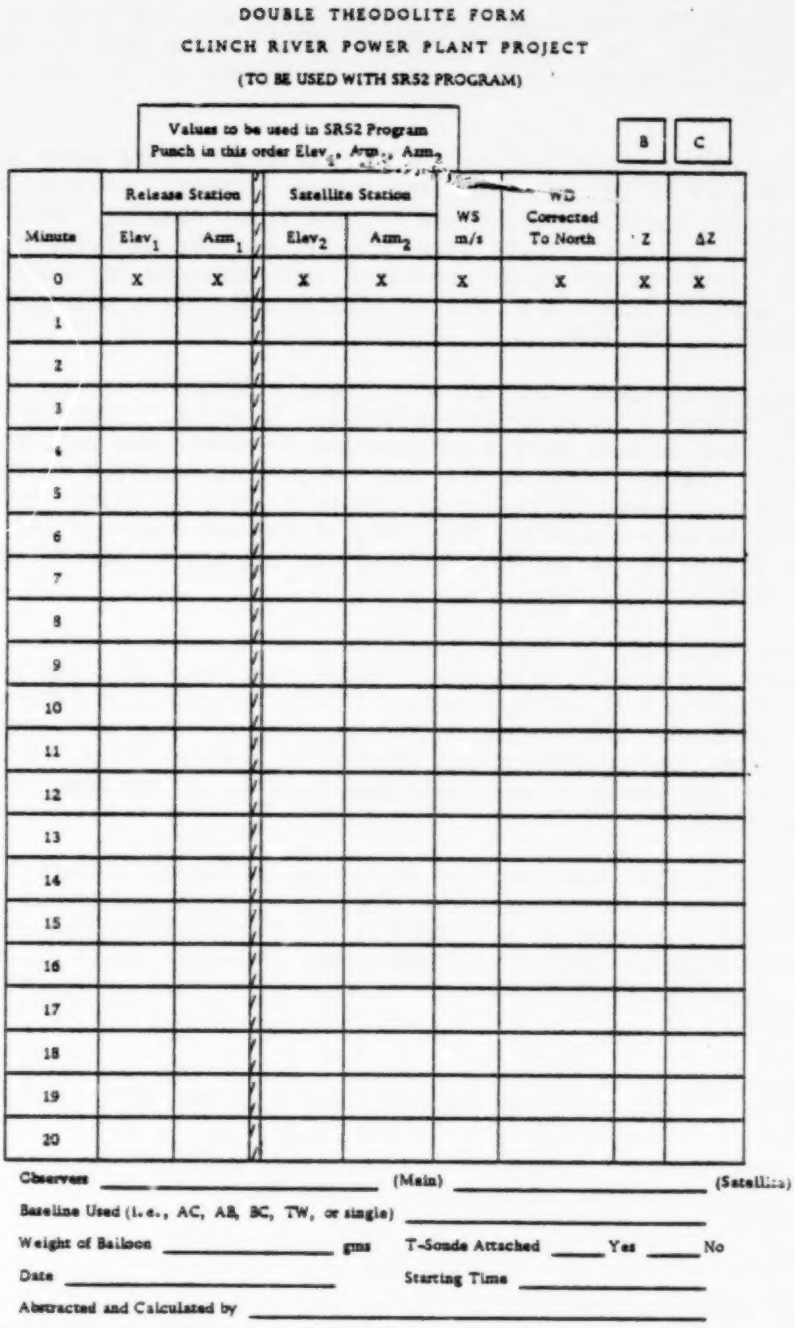
A log of all computer interventions was recorded on the form shown in Figure 11. A new log sheet was kept for each new tape recorded.

The form used to record data on which the plume travel was projected during a specific period is shown in Figure 30.

Calibration

Fixed Station Calibration--

The folowing procedure was followed when performing analyzer calibration at all the fixed stations. No adjustments were made to any analyzer until a complete investigation was made to determine the reason for the drift of an instrument.



DOUBLE THEODOLITE FORM

CLINCH RIVER POWER PLANT PROJECT

(TO BE USED WITH SR52 PROGRAM)

Values to be used in SR52 Program
Punch in this order Elev$_1$, Azm$_1$, Azm$_2$

B C

Minute	Release Station		Satellite Station		WS m/s	WD Corrected To North	Z	ΔZ
	Elev$_1$	Azm$_1$	Elev$_2$	Azm$_2$				
0	X	X	X	X	X	X	X	X
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

Observers ____________________ (Main) ____________________ (Satellite)

Baseline Used (i.e., AC, AB, BC, TW, or single) ____________________

Weight of Balloon ________________ gms T-Sonde Attached _____ Yes _____ No

Date ____________________ Starting Time ________________

Abstracted and Calculated by ______________________________

4/77

Figure 26. Double theodolite form.

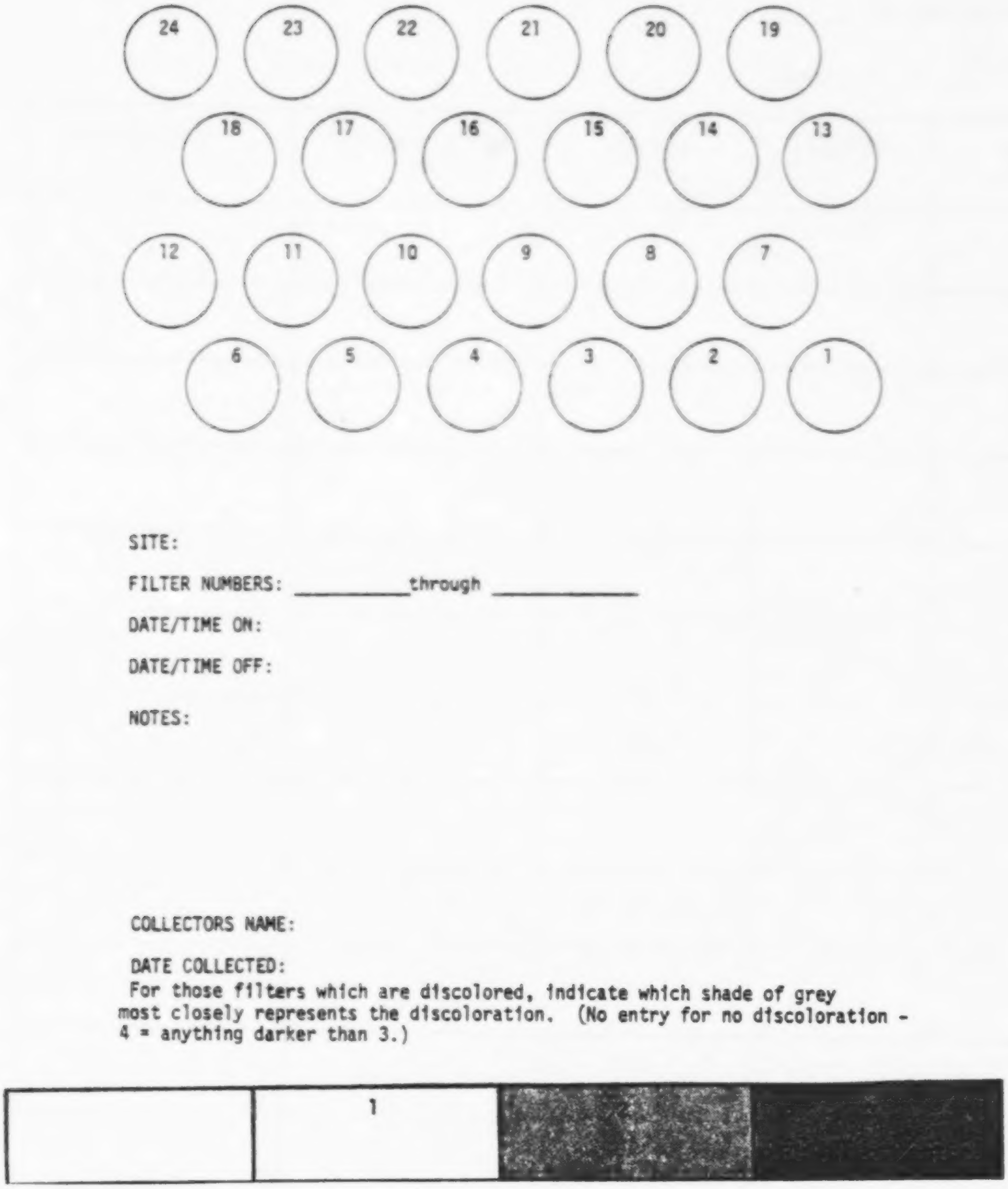
T-SONDE DATA REPORT

ABSTRACTED BY _______

DAY: ________________

TIME ( )	HEIGHT ( )	SCALE (1-8)	SONDE READING	TEMPERATURE (°C)

Figure 27. T-Sonde data report.


24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

SITE:

FILTER NUMBERS: __________through ____________

DATE/TIME ON:

DATE/TIME OFF:

NOTES:

COLLECTORS NAME:

DATE COLLECTED:

For those filters which are discolored, indicate which shade of grey most closely represents the discoloration. (No entry for no discoloration - 4 = anything darker than 3.)

1

Figure 28. Sulfate sample collection form.

T-SONDE DATA REPORT

ABSTRACTED BY ______

DAY: ________________

TIME ( )	HEIGHT ( )	SCALE (1-8)	SONDE READING	TEMPERATURE (°C)

Figure 27. T-Sonde data report.

SULFATE SAMPLING LOG - MOBILE UNITS

Mobil Unit - Suburban ______, Helicopter ______

Grab Sampler # 1 _____ (A.C.) # 2 _____ (D.C.)

Observer ____________________

Date	Filter Number	Time On	Time Off	Indicated Flow On	Indicated Flow Off

Notes:

Figure 29. Mobile sulfate data form.

Plume Projection Form

Clinch River Power Plant Project

Date __________________

Observer __________________

Time	HOCKEY		TOWER		Distance* (km)	T (Tower) (°C)	Plume Height
	Wind Speed	Wind Direction	Wind Speed	Wind Direction			
0500							
0600							
0700							
0800							
0900							
1000							
1100							
1200							
1300							
1400							
1500							
1600							
1700							
1800							
1900							
2000							
2100							

* If Tower wind speed is used to calculate distance, please note by putting "T" in the column next to the distance. Multiply by 3.6 to convert wind speed in (m/sec) to kilometers travelled in one hour.

Figure 30. Plume travel projection form.

The multipoint check was performed as follows:

Calibrator Steps:

1. Disconnect calibrator from computer command by removing eight-pin ampherol connector at rear of calibrator.

   Note: Calibrator should be in STBY state when making this disconnection (see Figure 31).

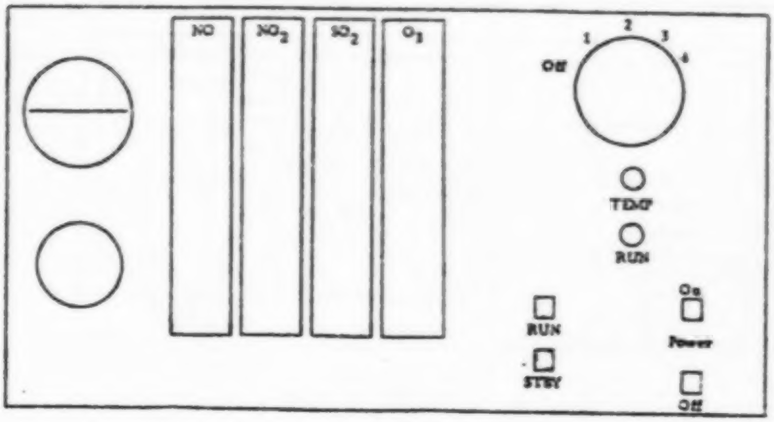


Figure 31. Model 8500 Calibrator

2. Install eight pin ampherol connector (with jumper between pin A & B) into the same socket that the computer link was removed from.

3. Turn calibrator to run position (see Figure 31).

SO_2 Instrument Steps:

1. Turn Monitor Labs 8450 Sulfur Analyzer to zero mode by depressing the zero button on the front panel (see Figure 32).

2. Allow analyzer 1/2 hour to stabilize on zero air. After this period has been completed, read the concentration on the digital display of 9400 Data Logger and record the value on the calibration graph.

3. Turn Monitor Labs 8450 Sulfur Analyzer to span mode by depressing the front panel span button (see Figure 32).

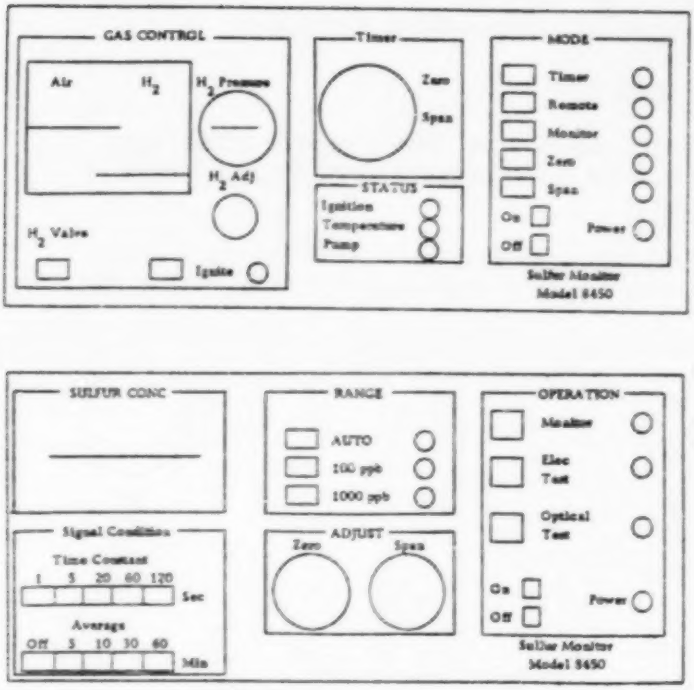

GAS CONTROL
Air
H2
H2 Pressure
H2 Adj
H2 Valve
Ignite
Timer
Zero
Span
STATUS
Ignition
Temperature
Pump
MODE
Timer
Remote
Monitor
Zero
Span
On
Off
Power
Sulfur Monitor
Model 8450
SULFUR CONC
Signal Condition
Time Constant
1 5 20 60 120
Sec
Average
Off 5 10 30 60
Min
RANGE
AUTO
100 ppb
1000 ppb
ADJUST
Zero
Span
OPERATION
Monitor
Elec Test
Optical Test
On
Off
Power
Sulfur Monitor
Model 8450

Figure 32. 8450 Sulfur Monitor

4. Set the SO_2 flowmeter on the Monitor Labs 8500 calibrator for an actual flow rate of 2500 cc/min.

5. Allow 1/2 hour for the analyzer to stabilize on span gas and then record the concentration on the calibration graph.

6. Continue recording span concentrations for 2000, 1500, and 1000 cc/min. calibrator flow rates.

   Note: Wait 15 minutes between recordings to allow for stabilization at a given concentration.

7. Return Monitor Labs 8450 Sulfur Analyzer to monitor mode by depressing front panel remote button (see Figure 32).

8. In addition, the following information should be recorded on the calibration graph.

   a) Time out of service
   b) Time in service

c) H_2 flow
d) Range
e) Time constant
f) Calibrator temperature
g) Calibrator serial number
h) Analyzer serial number.

Oxides of Nitrogen Instrument Steps:

1. Place toggle switch, on back of Monitor Labs 8440 Oxides of Nitrogen Analyzer, in zero position (up).

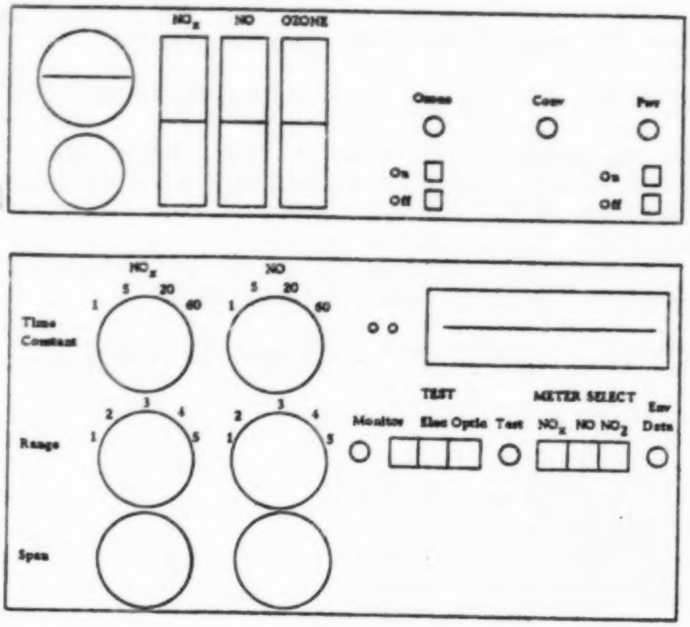

NO_x
NO
OZONE
Ozone
Conv
Pwr
On
Off
On
Off
NO_x
NO
Time Constant
1
5
20
60
Range
1
2
3
4
5
Span
TEST
METER SELECT
Monitor
Elec
Optic
Test
NO_x
NO
NO_2
Env Data

Figure 33. Model 8440 nitrogen oxide analyzer.

2. Allow unit to stabilize in the zero mode for 1/2 hour.

3. Record results on calibration curve.

   Note: Do not use front panel meter for NO_x concentrations. The results should be read on the display of the 9400 Data Logger.

4. Place the toggle switch at the rear of the analyzer in the span position by pressing the switch all the way down.

5. Adjust the NO rotometer of the 8500 calibrator to give an actual flow at 2500 cc/min.

6. Allow 1/2 hour for the analyzer to stabilize.

7. Record the NO, NO_x concentration on the calibration curve.

8. Record concentrations for calibrator flow rates of 2000, 1500 and 1000 cc/min. allowing 15 minutes for stabilization at each concentration.

9. Disconnect the supply hose from the intake filter.

10. Connect NO_2 supply line from 8500 calibrator.

11. Allow 20 minutes for the analyzer to stabilize.

12. Adjust NO_2 rotometer to flows of 2500, 2000, 1500, 1000 cc/min and record corresponding concentrations as read from 9400 display.

13. Plot graph of NO_2 input versus output and calculate converter efficiency, i.e., output/input.

14. Record the following on the calibration graph:

    a) NO, NO_x, O_3 flow rates
    b) Range
    c) Time constant
    d) Time taken out of service
    e) Time in service
    f) Calibrator temperature
    g) Analyzer serial number
    h) Calibrator serial number.

15. Return the Monitor Lab Oxides of Nitrogen Analyzer to the monitor mode by placing the zero-span toggle switch, at the rear of the analyzer, to the center position which is marked remote.

Calibrator Steps:

1. Turn the Monitor Labs 8500 calibrator to STBY position.

2. Remove the eight-pin ampherol jumper plug from the calibrator and replace the computer command plug at the same location.

3. Return the Monitor Labs 8500 calibrator to the run position.

4. If SO_2 or oxides of nitrogen concentrations are more than 20 percent from the theoretical values, an investigation should take place to determine the problem before any adjustments are made.

Calibration Curves--

Field calibration curves for NO_x, NO, and SO_2 were generated and identified using the following information:

1. A theoretical curve based on the flow rate of the calibrator for theoretical span concentrations
2. An actual curve of indicated flow rate of the calibrator versus concentrations measured by the analyzer at the same indicated flows that are used in the theoretical curve
3. Calibrator temperature
4. Calibrator serial number
5. Analyzer serial number
6. Time out of service for calibration
7. Time in service after completion of calibration
8. Zero concentration
9. For SO_2: H_2, sample (air) flow
10. For Oxides of Nitrogen: NO_x, NO, and O_3 flows.

Hi-Volume Sampler--

The Misco 24-port sequential sampler was calibrated with an orifice calibrator that has been referenced to a positive displacement meter. The procedure for individual port calibration was as follows:

1. Turn remote switch to local and remove filters from retaining rings
2. Connect orifice to sampling head per manufacturer's instructions
3. Connect U-tube manometer to port on orifice can
4. Place new circular chart on recorder

5. Set sequences to port #1 and turn hi-vol to on position; allow about 3 to 5 minutes for flow to stabilize

6. Note orifice number, change in height of water in manometer and chart deflection.

7. Repeat procedure for 23 additional ports.

8. Change orifice restriction and repeat procedure for all 24 ports (should be done for at least four restrictions, #5, #9, #10, #15).

9. Allow a single port to run for one sampling increment. Record the exact sampling time run and the reset time from the end of the sampling run to the start of sampling for the next port.

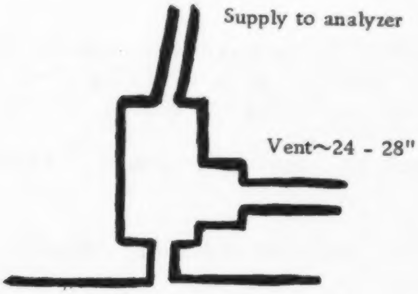
10. Return sampler to remote operation after replacing filters.

Flow Calibration--

8500 Calibrator--All flows in each calibrator were checked every 6 months to verify the dilution effects. The following procedure was followed:

1. Observe the sample outputs on rear of 8500 calibrator (should be 2 to 4 outputs depending on calibrator).

2. Note that each output consists of a supply line and a vent.



3. Remove supply to analyzer and cap opening.
4. Connect bubble flow meter to vent line. (Set up meter per manufacturer's instructions.)
5. Adjust rotometer to desired position (i.e., 2500, 2000, 1500, 1000 or 500 cc/min.).
6. Generate bubbles in flow meter.
7. Record length of time that bubble takes to traverse limits of volume. (Note volume may have to be changed to get good reading of time required.)
8. Repeat process for remaining flows on each parameter.
9. Repeat for all parameters.
10. Plot graph of indicated flow versus actual flow and record indicated flows for 2500, 2000, 1500, 1000, and 500 cc/min.
11. Unplug supply line and reconnect supply line.

NO Supply Flow--

1. Open cover of 8500 calibrator.
2. Remove NO capillary supply line from tee connection.
3. Connect capillary to bubble flow meter.
4. Generate bubbles and record time to traverse the designated volume.
5. Repeat procedure for different NO flows which are regulated by the front panel NO pressure regulator.
6. Reconnect NO capillary to dilution Tee.

Mobile Calibrations (Ground and Airborne)

In calibrating instruments in the van and the helicopter readings were taken with instruments connected to the field generator power supply. The mobile calibrator was placed inside the vehicle and put in the RUN mode. Calibration graphs were prepared with the same information that appeared in the fixed station procedure.

SO_2 Calibrations--The procedure for calibrating the SO_2 analyzers was as follows:

1. Connect zero air supply to Theta Sensor intake.
2. Allow to stabilize 15-20 minutes.
3. Make necessary adjustments for zero reading.
4. Record reading of what appears on assigned channel of data logger.
5. This reading will be volts and must be converted to ppm.
6. Disconnect zero supply and connect SO_2 supply to intake.
7. Adjust 8500 calibrator SO_2 channel to a rotometer reading of 1500 cc/min.
8. Allow to stabilize for 15-20 minutes.
9. Make necessary adjustments to Theta Sensor for proper span.
10. Repeat procedure for 2500, 2000 and 1000 cc/min dilution flows and plot on calibration graph.
11. Return Theta Sensor to sample mode by reconnecting sample line to intake.

$NO-NO_x$ Calibrations--Because an NO dilution system did not exist in the mobile calibrator, NO_2 was used as the calibration gas for the $NO-NO_x$ instrument. This was done by passing NO_2 through the Molybdenum converter in the 8440 NO_x analyzer and utilizing the efficiency of the converter. The converter efficiency was determined at a fixed station that had an NO dilution supply. This measuremement was made every 3 to 4 months. The calibration procedure followed in the mobile vehicles was:

1. With NO_x analyzer in proper operating mode, connect zero supply to intake.
2. Allow system to settle for 15-20 min.
3. Make necessary zero adjustments and record final reading on calibration graph.
4. Introduce NO_2 supply to 8440 NO_x analyzer.
5. Adjust NO_2 rotometer in 8500 calibrator to 1500 cc/min.

6. Allow system to stabilize 15-20 minutes and then make necessary span adjustment to NO_x channel only.

7. Record reading of NO_x calibration graph.

8. Repeat for dilution flows of 2500, 2000, and 1000 cc/min.

9. Interchange the NO and NO_x interconnect lines on back of 8440 NO_x analyzer. This is done to allow NO_2 supply to pass through converter so that the NO channel may be calibrated.

10. Set NO_2 dilution flow to 1500 cc/min.

11. Allow system to stabilize for 15 to 20 minutes and record final output.

12. Repeat for dilution flows of 2500, 2000 and 1000 cc/min.

13. NO concentrations must be adjusted using NO_2 - NO converter efficiency by the following:

$$(NO_2 \times \text{Converter Efficiency}) = (NO)$$

14. The NO and NO_x interconnect lines must be returned to the proper connection mode for proper instrument operation.

15. Return 8440 NO_x analyzer to the sample mode by connecting supply line to intake.

Ozone--The procedure for calibrating the ozone analyzers was as follows:

1. Connect zero supply to intake of 8410 ozone analyzer.

2. Allow to stabilize 15-20 minutes.

3. Make necessary zero adjustments and record data on calibration graph.

4. Turn 8500 calibrator ozone generator to setting #1, set dilution to rotometer 1500 cc/min. and allow system to stabilize for 30 minutes.

5. Make necessary span adjustments and record on calibration graph.

6. Repeat procedure for dilution flows of 2500, 2000 and 1000 cc/min.

7. Turn ozone generator off and return 8410 ozone monitor to sample mode by connecting supply line to intake.

Sulfate Sampler--The Misco 800 grab sampler is calibrated using the orifice calibrator and a water manometer:

1. Connect orifice to front of grab sampler.

2. Connect manometer to port on orifice can.

3. Turn 8000 grab sampler on and record manometer reading along with sampler gauge reading.

4. Repeat for orifice restrictions of #5, #7, #10 and #15.

5. Mount filter on grab sampler.

6. Plot graph of grab sampler gauge reading versus manometer change in height.

Data Editing

The editing and correction of data collected in the field program started in the field as the field observers scanned the computer printer output and observed the performance of the instruments. The observers had the capability of editing data directly in the field or even taking instruments off line so that data were deleted if it appeared the instrument was malfunctioning. Some data were actually reduced and analyzed in the field and used in the decision-making process relating to field operations.

After the data were received in Gaithersburg, additional screening was accomplished and those data were presented in quarterly reports to the project officer. After the aerometric measurements were completed, the data were thoroughly screened and edited into a final comprehensive data tape that is available from the National Technical Information Service.

Field Data Editing--

Upon arrival at the power plant in the morning, the first item of business was to scan the computer printout for continuity of data from the field sensors. All zero and span values were checked to see that each instrument performed that sequence at the proper time during the night as well as checking for the reasonableness of the values.

A scan of the meteorological parameters was made to check the reasonableness of the temperature sensors at the various stations. If one station was recording a temperature in large variance to the majority of other stations, and no reasonable explanation was readily available, then that sensor was marked for checking and added to the maintenance list of items to be covered. The same procedure was followed for the wind speed and wind direction sensors. The wind direction sensors sometimes showed large variations during light wind conditions due to their being affected by local terrain-induced flows on certain occasions. Local effects could be a dominate feature in wind values that do not correspond with other stations. These considerations were evaluated before effort was expended to visit the site to check the sensor.

So that the results of the double theodolite and T-Sonde data could be readily available for use in directing the mobile sampling vehicle, a programmable hand calculator (Texas Instrument SR-52) was available for use by the field personnel. The field procedure was to record the azimuth and elevation angles on a voice recorder; transcribe these angles onto a double theodolite recording form prepared especially for this project; enter the angles into a SR-52 programmable calculator; and record the calculated wind speed, wind direction, height and change in height of the balloon at each observation point.

After ascents with a temperature sensing device (T-Sonde) attached to the balloon, the strip chart record was reduced by field personnel who entered temperatures at appropriate heights on a form which presents a detailed temperature profile with height.

Office Editing--

All data were logged in and recorded as received in the Gaithersburg office, and a form documenting the data received was transmitted back to the field personnel to corroborate their records as to what was sent. All digital tapes were transmitted to the computing center (in the Gaithersburg office) and logged into their magnetic tape storage files. All other data were stored in their appropriate file or log book depending upon the type of data.

The zero and span values received from the field were recorded on computer forms for keypunching and merging into the appropriate zero and span files as maintained on the computer disk. Zero and span values for the fixed stations as well as the mobile stations were evaluated and keypunched.

The field data tapes were reblocked into convenient data records for handling on the PDP 11/70 computer available in the Gaithersburg office. As these data were reblocked, the zero and span corrections were applied to the air quality data and values for NO_2 were calculated. All data (instantaneous as well as hourly) were recorded on a system tape at high density, thus reducing the tape handling procedures for further analysis. Between seven to nine field tapes could be condensed onto one system tape by this process.

Simultaneous with the writing of the new system tape for the corrected field data, the hourly averages were abstracted out of the data set and recorded on the disk. This became the active working file from which the reports (both quarterly and final) were generated.

The disk files were then sorted by station and a print of these results was made available in hard copy form to the project personnel for reviewing and editing of any erroneous data.

The daily log records were reviewed so that any data that the field personnel indicated might be either questionable or erroneous were then scrutinized using the hard copy printout. Any data that could not be corrected was edited out as invalid data. Forms were available to the personnel screening the data to code corrections which were then entered into an edit program that replaced all incorrect or missing values with either a correct value or a missing indicator.

Plant operating data was obtained from the Clinch River Power Plant personnel and transmitted to the Gaithersburg office. These forms were given directly to keypunch personnel who had been trained to pick off and punch the appropriate numbers directly onto cards. These data were then placed on the disk file and merged with the air quality data for the printout of the fixed station data used in the quarterly reports. It was also used in the appendices which presented these data as plant operating data.

The sulfate analysis data were screened when the analysis was received from PEDCo in addition to the quality control that PEDCo performed. Any high values were usually brought to our attention by PEDCo with the indication that they had rechecked their calculations to confirm the correctness of these numbers. These sulfate measurements were corrected for background filter sulfate content. The adjusted measurements were then combined with the flow recorded for each high-volume sample to determine the air concentration mass per volume as presented in the report. Calibrations of the high volume samplers were used to correct the recorded flow rate in these calculations.

The first port of each high volume sampler was never turned on (the logical circuit was set up to initiate running on port 2) so that a check of any sulfate deposition on the filters while in the high volume sampler could be ascertained. All other ports (i.e., 2 through 24) were active ports which collected sulfates by drawing air through the filters.

Field Audits

Obtaining a complete and reliable air quality and meteorological data set is the primary objective of the Phase II Clinch River field project. To ensure quality, data were collected and on-site audits were conducted.

A series of four independent audits were carried out by members of Research Triangle Institute. Additionally, GEOMET instituted periodic checks of meteorological and air quality equipment.

The four audits performed by RTI consisted of the following:

1. System Audit (January 20 through 21, 1977)
2. Performance Audit #1 (February 15 through 23, 1977)
3. Technical Assistance Audit (July 12 through 14, 1977)
4. Performance Audit #2 (August 5 through 13, 1977).

The system audit was an evaluation of the GEOMET field project as a complete system. Of primary concern was the record-keeping system, data validation procedure, maintenance procedure, equipment installation and field personnel.

The first and second performance audits were dynamic calibration checks of all air quality equipment. This consisted of introducing a known pollutant concentration to an analyzer and obtaining the resultant output from the computer system. All samples introduced were NBS traceable and verified by laboratory techniques before and after the audit. SO_2 samples were generated by permeation tubes and dilution of SO_2 tank gas. NO concentrations resulted from the dilution of a concentrated NO tank supply, and gas phase titration of NO produced known NO_2 samples.

Temperature measurements were checked during the first audit by mounting an aspirated sensor on the roof of each sampling station and comparing to the output received at the base station.

Prior to the July intensive study, a technical assistance audit was conducted at the Munsey station. The purpose was to verify the data quality at the Munsey station, which was representative of the entire system, review any weaknesses that had been pointed out during the two prior audits and finally to make any suggestions that would assist GEOMET in obtaining a high percentage of quality data during the intensive study.

During the preliminary field audit, some basic weaknesses were pointed out. The particular items are listed below:

1. Traceability of calibration standards and permeation tubes to NBS-SRM's via supplier. Primary dependence upon the manufacturer's quality control.
2. Lack of flow devices to check volumetric flow rate within $\pm$ 2 percent accuracy. Flow devices not traceable to NBS.

3. Independent check (standard of higher accuracy) of NO standard not available.

4. Capability of verification of ozone generator output by KI method or apparatus to perform gas phase titration not apparent.

5. No quality assurance coordinator designated to insure maximum quality and quantity of data.

6. Possible altitude effects on airborne data, i.e., effect of altitude on analyzer calibration.

7. Zero air not checked against an independent source to define its quality.

8. Calibration of SO_2 analyzer not through sample inlet line, i.e., not through H_2S scrubber.

All traceability of calibration data pertaining to permeation devices and tank gas have been retained at the Gaithersburg office of GEOMET. This was a security procedure. An NBS traceable flow device was purchased in early April 1977. A check was then run against the flow device that had been in use. Because of problems experienced with the Monitor Labs 8440 NO-NO_x analyzer, an NBS traceable tank of NO gas was purchased and delivery took place in early November 1976. Initially, the tank was used to eliminate the NO-NO_x analyzer problems. Periodic checks (four to six months) were then made on all NO tanks in the field by comparing them to this NBS tank.

Ozone quality checks were made during all performance audits. A reliable gas phase titration device was not available during the Clinch River project.

The plumbing of the Monitor Labs 8450 sulfur dioxide analyzer was modified to allow calibration gas as well as sample air to pass through the H_2S scrubber. Tests were conducted to determine the influence of the H_2S scrubber on the calibration gases and no appreciable impact was observed. For the purpose of consistency, the new plumbing system was utilized.

Cross checks of calibration devices at all stations have been carried out on a periodic basis. This is accomplished with a portable calibrator that was checked against all other calibration devices. If a majority of stations yielded consistent results with one or two showing discrepancies then the calibrator was accepted and the stations showing variations were investigated. On the other hand, if all stations showed variation from the actual concentration, then the calibrator was suspected.

The two individual performance audits pointed out particular malfunctions with specific instruments. This information was the basis for investigations on those problems and subsequent repairs. Furthermore, data corrections could be made based on GEOMET calibration data for the periods when the instrument was in question.

GEOMET conducted periodic audits on an informal basis. Air quality equipment, consisting of calibrators, SO_2 and NO-NO_x analyzers, was checked in addition to wind speed and wind direction equipment.

SO_2 analyzers were checked against a known SO_2 concentration generated by a permeation device. Multiple points were checked to ensure reliability through the entire instrument range. Oxides of nitrogen analyzers were referenced to an NBS traceable NO supply. After a multipoint NO calibration was performed, NO_2 samples generated from a permeation tube were introduced and compared to the NO calibration. This served two purposes: first a check of the NO calibration technique; second, and most important, a measure of the Molybdenum converter's (NO_2 to NO) efficiency could be obtained.

Wind direction sensors were oriented to a known location that could be identified on a topographic map and verified by a compass. Wind speed sensors were checked electronically by generation of a known signal corresponding to a particular wind speed. The resultant wind speed was then compared to the input data.

High-volume samplers were tested for flow versus chart reading by utilizing an orifice calibration device. The orifice calibrator was supplied with a calibration curve which was then checked against a positive displacement meter.

SECTION 5

RESULTS

OVERVIEW

The field data which were collected over a 16-mo period between June 1, 1976 and September 30, 1977 are recorded on magnetic tape. They are also tabulated in preliminary form in five quarterly reports. The data were collected at the 13 monitoring stations identified in Table 5. The characteristics of the 13 stations, which are described in detail in Section 4, are summarized in Table 5 by 11 types of measurements. Four of the measurements are aerometric measurements of pollutants in the air, including sulfur dioxide, nitrogen oxides (i.e., NO and NO_x), ozone, and, sulfate aerosols. The remaining seven measurements are meteorological measurements, including wind speed and direction, temperature, relative humidity, precipitation and ultraviolet radiation intensity. At some stations vertical profiles of temperature and/or wind can be constructed from the observations made at two or more heights.

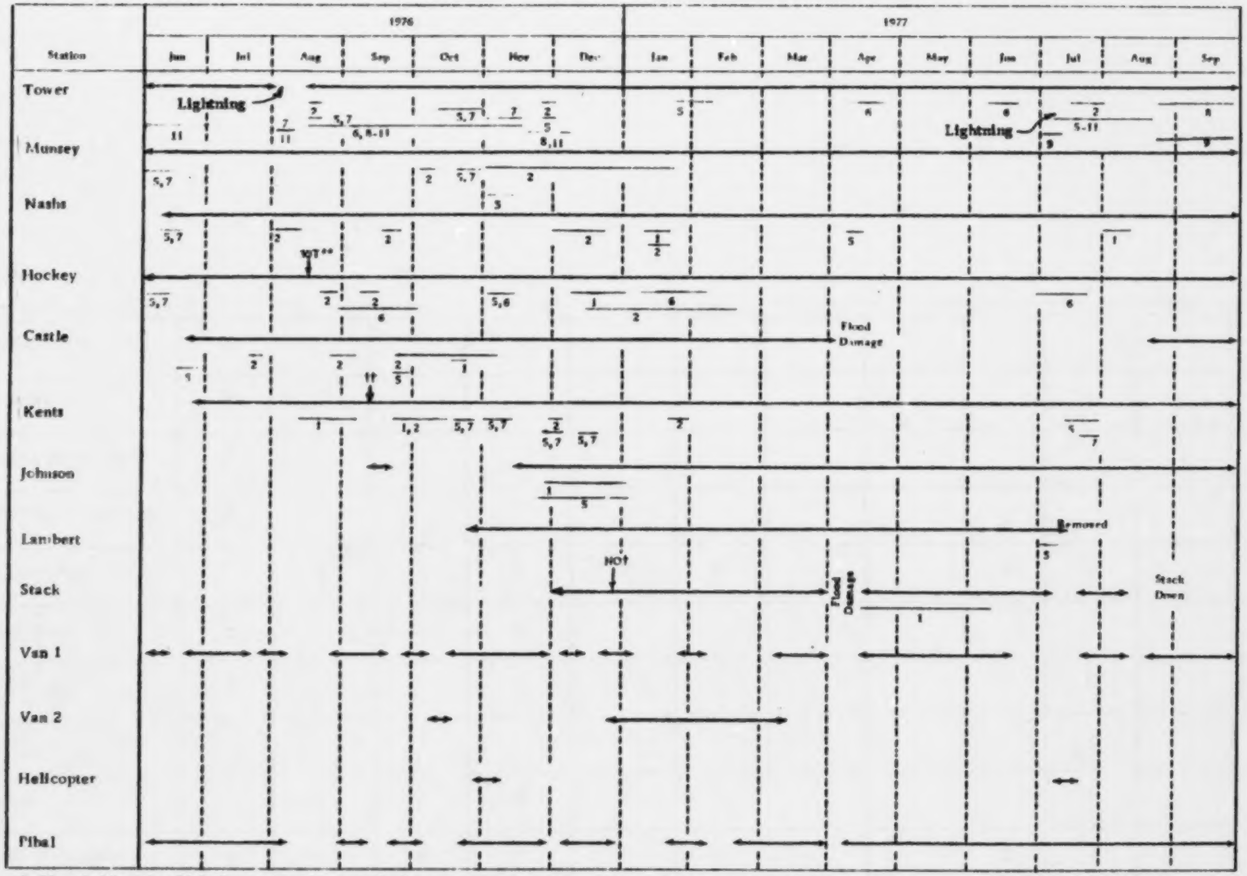
Figure 34 shows when during the operating period each station became operative and when there were major periods of down time of five days or more. The heavy lines with arrowheads at each end indicate periods when the station was collecting data. The light lines without arrowheads show periods of down time of five days or more when various measurements were not being taken. The numbers below the lines refer to the measurements listed in Table 5 to identify the types of measurements which were not operational.

Figure 34 provides a convenient index of the types of data which are available for various parts of the field monitoring operations. The six primary monitoring stations which measured SO_2, NO, NO_x, wind speed and direction, and temperature were operational from July 1 to the end of the period, except for the Castlewood station. A flood on April 5, 1977, washed the Castlewood station away. In July, the Lambert station was moved to the Castlewood site which was provided with full utility service in August. Two supplementary stations which measured SO_2 and wind speed and direction became consistently operational in November. The stack monitor was also installed in November to begin measuring SO_2 emissions. The NO emission measurements became operational in December. The stack monitor was put out of commission briefly when the plant shut down suddenly due to the April flood. Another significant weather phenomenon which seriously disrupted the monitoring network was summer thunderstorms. Lightning strikes on the tower knocked out the meteorological instruments once each summer.

TABLE 5. PARAMETERS MEASURED AT MONITORING STATIONS.

Measurement	Station												
	Tower	Munsey	Nash's Ford	Hockey	Castle-wood	Kent's Ridge	Johnson	Lambert	Stack	Mobile 1	Mobile 2	Heli-copter	Pibal
1. SO_2	X	X	X	X	X	X	X	X	X	X	X	X	
2. Nitrogen Oxides	X	X	X	X	X	X			X	X		X	
3. Sulfates		X	X	X	X	X				X			
4. Ozone										X		X	
5. 10 m wind	X	X	X	X	X	X	X	X		X			
6. 30 m wind	X			X									X*
7. Temperature	X	X	X	X	X	X			X	X		X	
8. Temperature Profile	X											X	X
9. Relative Humidity	X											X	
10. Precipitation	X												
11. UV Radiation	X												

* Wind profile.



* Lines (without heads) indicate time that a particular measurement was not operational. The numbers designate the measurement types listed in Table 5.

** Designates installation of 30 m tower.

† Designates installation of NO analysis.

†† Station put on line to computer.

Figure 34. Monitoring station operating periods.

The pibal station and mobile van were manned fairly continuously; however, there were several periods scattered throughout the study when only one or two operations a week were conducted with pibals or the van. These periods are shown in Figure 34. There was a period from January to March when a second van was used to supplement the mobile sampling operation.

The two most intensive monitoring periods were conducted using a helicopter to make repeated passes through the plume. One 10 d period of helicopter operations was performed during November, and the second 10 d period was performed in July 1977.

The procedures followed to control the quality of data were tested by independent measurements made by organizations other than GEOMET or its subcontractors or suppliers. Field performance audits were conducted by an independent contractor hired by EPA. Fifteen strips containing unknown quantities of integrated sulfates were furnished by EPA and submitted to the laboratory which performed the sulfate analysis. The stack gases were measured by an independent contractor using the EPA reference method to compare with simultaneous measurements by the automated continuous stack monitor.

Two independent audits of the monitoring instruments were performed by Research Triangle Institute. In the first audit, conducted during the period of February 15 to 23, 1977, measurements of SO_2, NO, NO_x, NO_2 and, temperature were tested at the eight fixed monitoring trailers and in the primary van (Smith et al., 1977). The effects of variations in CO_2 concentrations on the SO_2 analyzers were also examined.

The SO_2 analyzers at the eight fixed monitoring stations were tested with five audit concentrations, including a zero value, concentrations near 50, 100 and, 150 ppb, and a higher value which varied from 350 to 850 ppb at different stations. A summary of the measured audit concentrations at each station and the station analyzer responses are listed in Table 6. One instrument (Lambert Station) was not performing properly on the day of the audit. The cause of the poor performance was later identified and corrected. The instruments are calibrated with span gases generated using a permeation tube in a system with a maximum output of about 150 ppb. The instrument responses compared to the audit values show that the absolute differences are smallest in the range of 0 to 150 ppb. Responses near the high audit value are more variable in absolute accuracy, although not in percentage differences. At the fixed stations only 1% or less of the recorded SO_2 concentrations are above 200 ppb. If one omits the highest measurements in the audit and the values for Lambert station, there are 28 remaining responses to audit comparisons. The root-mean-square difference of these 28 values is 10 ppb which is about the expected accuracy of the instrument. Because the instrument was

TABLE 6. SUMMARY OF SULFUR DIOXIDE AUDIT RESULTS, FEBRUARY 15-23, 1977.

Station Name (Purchase date of analyzer)	Audit Date	Analyzer Range (ppb)	Audit SO_2 (ppb)	Response SO_2 (ppb)	Difference (d) (response-audit)		Regression of audit on response A = mR + b	
					ppb	%	m	b
Castlewood	2/15/77	0-1000	0	10	+10	-	1.13	-2.73
(Feb.-Mar., 1976)			50	37	-13	-26		
			109	92	-17	-16		
			138	135	-3	-2		
			544	484	-60	-11		
Johnson	2/16/77	0-1000	0	0	0	-	1.07	1.59
(Feb.-Mar., 1976)			65	58	-7	-11		
			127	116	-11	-9		
			188	175	-13	-7		
			349	325	-24	-7		
Hockey	2/17/77	0-1000	0	4	+4	-	0.977	-10.5
(Feb.-Mar., 1976)			50	57	-7	-14		
			96	110	+14	+15		
			146	174	+28	+19		
			721	746	+25	+3		
Munsey	2/18/77	0-1000	0	5	+5	-	1.12	-2.99
(Feb.-Mar., 1976)			51	46	-5	-10		
			97	88	-9	-9		
			150	139	-11	-7		
			725	536*	-189	-26		
Lambert	2/19/77	0-1000	0	0	0	-	1.60	-1.05
(Feb.-Mar., 1976			51	80	+29	+57		
			96	160	+64	+67		
			148	251	+103	+70		
			468	787	+319	+68		
Tower	2/20/77	0-1000	0	1	+1	-	0.938	2.45
(Feb.-Mar., 1976)			51	46	-5	-10		
			96	101	+5	+5		
			149	157	+8	+5		
			460	678	+218	+47		
Nash	2/21/77	0-1000	0	-1	-1	-	1.15	-6.59
(Feb.-Mar., 1976)			51	40	-11	-22		
			99	95	-4	-4		
			145	149	+4	+3		
			841	732	-109	-12		
Kent	2/22/77	0-500	0	-2	-2	-	0.847	5.21
(Feb.-Mar., 1976)			46	43	-3	-6		
			87	94	+7	+8		
			138	161	+23	+17		
			340	395	+55	+16		

* Data point does not fit linear pattern and was not included in calculation of regression coefficients.

not routinely calibrated for higher concentrations, values above 200 ppb are associated with a higher degree of uncertainty. The audit results found the instruments varied from 26% below to 16% above audit values (excluding Lambert) at high concentrations (between 340 and 841 ppb). The root-mean-square percentage difference was 13% for these higher values.

The Lambert SO_2 measurements were a special situation during the first audit. The results in Table 6 show that these measurements were consistently higher than audit values by 57 to 70%. After the audit it was discovered that there was a marked increase in the instrument response when the calibration gas was introduced through the instrument "sample port" (as was done in the audit evaluation) rather than through the instrument "span port" as was routinely done in the field calibrations). When the instrument solenoid valve was replaced there was no difference between readings for span gas introduced through the two ports. Since the span readings are quite consistent prior to changing the solenoid valve, it is assumed that the solenoid was defective from its initial installation. The dilution effect of the faulty solenoid valve on the span gas used to calibrate the instrument prior to replacement is relatively constant. Thus it has been possible to correctly interpret the instrument response to the span gas by taking the dilution effect into account and assuming the SO_2 content of the diluting ambient air is zero.

During the audit it was demonstrated that high CO_2 concentrations can interfere with SO_2 analyzer readings. The effect, expressed as a percent of the SO_2 reading, is independent of SO_2 concentration, but it varies from an average depression of 5% at a CO_2 concentration of 360 ppm to an average depression of 15% at 750 ppm. The difference between CO_2 concentrations in ambient air and in the dilution air used to calibrate the instruments was tested once each day during the audit at whichever station was being audited that day. The average difference was 126 ppm with a range of +23 to -324 ppm. These results suggest that the suppression effect is generally less than 5%. The greatest uncertainty is likely to occur with very high SO_2 measurements. The magnitude of the maximum effect is expected to be about a 15% depression in the reading from the actual concentration.

The NO-NO_x analyzers at five fixed stations and in the mobile van were tested for response to NO, NO_2 and, total oxides of nigrogen. The fixed stations were tested for each gas with concentrations near 400 ppb, near 800 ppb, and, a higher value (for NO and NO_x only). The van was tested with concentrations near 200 and 400 ppb. The audit concentrations are close to the concentrations of the span gases used to calibrate the instuments; however, these are much higher than are normally measured. The results of the audit for concentrations near 400 ppb are shown in Table 7. The results for Munsey show that this instrument was not functioning properly. The source of the problem was corrected shortly after the audit. The mean percentage differences between response and audit values for NO, NO_x, and, NO_2 were -2%, +3%, and, +18%, respectively, when the Munsey station results are omitted. The root-mean-square percentage differences were 9, 11, and 21%, respectively. Since NO_2 is determined as the difference between NO_x and NO measurements, it is not surprising that a larger error is associated with NO_2 than with either of the other two measurements. The audit results for the higher concentrations were similar to those presented in Table 7.

TABLE 7. SUMMARY OF NITROGEN OXIDES AUDIT RESULTS, FEBRUARY 15-23, 1977.

	Concentrations				
				Difference (Response-Audit)	
Station	Gas	Audit Level (PPB)	Analyzer Response (PPB)	(PPB)	%
Castlewood	Zero	0	- 1	1	-
	NO	374	428	+ 54	+ 14
	NO_x	374	420	+ 46	+ 12
	NO_2	398	519	+121	+ 30
Munsey	Zero	0	- 2	- 2	-
	NO	383	699	+336	+ 93
	NO_x	363	693	+330	+ 91
	NO_2	312	649	+337	+108
Tower	Zero	0	- 3	- 3	-
	NO	428	427	- 1	0
	NO_x	428	487	+ 59	+ 14
	NO_2	398	483	+ 85	+ 21
Nash	Zero	0	- 3	- 3	-
	NO	401	360	- 41	- 10
	NO_x	401	354	- 47	- 12
	NO_2	398	416	+ 18	+ 5
Kent	Zero	0	6	+ 6	-
	NO	371	334	- 37	- 10
	NO_x	371	348	- 23	- 6
	NO_2	398	513	+115	+ 29
Van	Zero	0	4	+ 4	-
	NO	404	394	- 10	- 2
	NO_x	404	435	+ 31	+ 8
	NO_2	312	333	+ 21	+ 7

The temperature sensors at six fixed monitoring stations and the van were audited. The mean difference between audit and response temperature was 0.6°C. The root-mean-square difference was 0.9°C. The small differences which did occur could be attributed to differences in location of the audit and network sensors which were not always at the same heights above ground. Differences of as much as 20 feet were present during some of the comparisons.

A second field audit was performed during the period of August 5 to 12, 1977, by Research Triangle Institute (Frazier and Williams, 1977). One ozone, six oxides of nitrogen and three sulfur dioxide analyzers were audited following procedures used in the first audit. The ozone analyzer response in the van differed from the audit test concentrations by no more than 10 ppb, which is within the instrument accuracy, when challenged by concentrations of 0, 30, 70, 110 and, 160 ppb of ozone.

The oxides of nitrogen analyzers at six stations were tested, including the van. As in the previous audit the audit concentrations were much higher than the normally measured ambient air concentrations. It is also observed in the audit results that the percentage difference between audit and response concentrations increases with increasing concentration. In order to get an error estimate that is representative of the values normally measured, we have determined the root-mean-square percentage difference between audit and response concentrations for audit concentrations below 600 ppb. For all NO and NO_x comparisons this includes responses to a single audit value of 560 ppb at each site. For NO_2 comparisons this includes responses to two or three audit values since varying concentrations of NO_2 were used at each station. The results obtained for the van show that it is clearly not operating properly. The source of this problem was later identified and corrected. The audit results for the van have not been used in estimating the uncertainty of the network oxides of nitrogen observations. The results presented in Table 8 show that the mean errors of NO, NO_x and, NO_2 are 4, 3 and, 8%, respectively, averaged over the five good measuring stations; the root-mean-square percentage errors are 10, 8 and, 15%, respectively.

Sulfur dioxide analyzers at three stations were audited. In contrast to the first audit, higher concentrations were tested in the second audit with the results listed in Table 9. Audit results for measurements below 400 ppb are most relevant to the ambient air measurements compiled in the field program. The mean percentage difference between audit and response concentrations below 400 ppb (excluding 0 values) was 1%; the root-mean-square percentage difference was 8%.

In order to estimate the accuracy of the laboratory assessment of sulfate content on the filters submitted for analysis, a set of filters with known sulfate amounts embedded in the filters was obtained from EPA. The PEDCo laboratory analysis of these filters is presented in Table 10. The sulfate content varied from 0 to 6550 µg. The results show that the difference between the embedded amounts and the measured values is best expressed as an absolute difference rather than a percentage of the embedded amount. The mean difference was 109 µg, and the root-mean-square difference was 223 µg. The higher measurement results may be due to the tendency of the

TABLE 8. AUDIT RESULTS FOR OXIDES OF NITROGEN ANALYZERS, AUGUST 5-12, 1977

	Concentrations				
Station	Gas	Audit (PPB)	Analyzer Response (PPB)	Difference (Response-Audit) (PPB)	%
Tower	Zero	0	10	10	-
	NO	560	640	80	14
	NO_x	560	600	40	7
	NO_2	240	220	- 20	- 8
		330	330	0	0
		590	630	40	7
Munsey	Zero	0	0	0	-
	NO	560	600	40	7
	NO_x	560	580	20	4
	NO_2	340	380	40	12
		490	590	100	20
Kent's Ridge	Zero	0	0	0	-
	NO	560	620	60	11
	NO_x	560	590	30	5
	NO_2	260	250	- 10	- 4
		360	380	20	6
		580	630	50	9
Nash's Ford	Zero	0	0	0	-
	NO	560	540	- 20	- 4
	NO_x	560	630	70	12
	NO_2	260	340	80	31
		360	490	110	29
Hockey	Zero	0	0	0	-
	NO	560	510	- 50	- 9
	NO_x	560	500	- 60	-11
	NO_2	220	200	- 20	- 9
		300	320	20	7

TABLE 9. SULFUR DIOXIDE ANALYZER RESULTS
FROM AUDIT OF AUGUST 5-12, 1977

Station Name	Analyzer Model and S/N	Concentration (ppm)	Analyzer Response (ppm)	Difference		Regression on Analyzer Response on Audit Concentration Y = mX + 3		
				PPM	Percent	m	b	r
Munsey	Monitor Labs	0.00	0.02	0.02	--	0.998	0.004	0.9990
	Model 8450	0.20	0.18	-0.02	-10.0			
	S/N 85	0.38	0.38	0.00	0.0			
		0.48	0.49	0.01	2.1			
		0.66	0.67	0.01	1.5			
		0.87	0.87	0.00	0.0			
Kent's	Monitor Labs	0.00	0.01	0.01	--	1.126	0.004	0.9996
Ridge	Model 8450	0.20	0.22	0.02	10.0			
	S/N 128	0.38	0.43	0.05	13.2			
		0.48	0.55	0.07	14.6			
Hockey	Monitor Labs	0.00	0.01	0.01	--	0.882	0.021	0.9987
	Model 8450	0.20	0.19	-0.01	- 5.0			
		0.38	0.37	-0.01	- 2.0			
		0.48	0.46	-0.02	- 4.2			
		0.66	0.61	-0.05	- 7.6			
		0.87	0.77	-0.10	-11.5			

m = slope   b = intercept   r = correlation coefficient

filter material to absorb SO_2, which is converted to sulfate during the process of transporting and handling the filters. Otherwise, the measurements are within the accuracy of the assessment technique.

In order to test the accuracy of the EDC stack gas analyzer, which measures NO and SO_2 concentrations in the breeching of one stack, the Engineering Science Company was hired under contract to EPA to measure the stack gases by the standard reference methods. Comparative tests were made during the 4-d period of November 15 to 18, 1977,(Engineering Science 1978). The comparisons for SO_2 measurements are presented in Table 11. The comparisons for NO measurements are presented in Table 12. The plant was operating its number three generator at a very constant and high-load level throughout the measurement period. The output averaged 240 megawatts and did not vary from the average by more than 1 or 2 megawatts. The EDC analyzer produced very consistent results which were continuously recorded on a strip chart. The SO_2 measurements showed a standard deviation of 12 ppm compared to a mean of 459 ppm or a variation of less than 3% of the mean. The stack samples drawn by probe and later analyzed in a laboratory showed a slightly higher mean of 479 ppm and over twice as much variation in the samples, i.e., a standard deviation of 27 ppm or about 6% of the mean.

TABLE 10. COMPARISONS OF EMBEDDED AMOUNTS OF SULFATE WITH LABORATORY ANALYSIS OF FILTER SULFATE.

Filter No.	Sulfate		Difference (Measured-Embedded) (μg)	Difference/Embedded %
	Embedded (μg)	Measured (μg)		
1204	200	425	225	113
1205	200	360	160	80
1211	200	300	100	50
1207	6550	6750	200	3
2159	6550	7000	450	7
2202	6550	6750	200	3
3338	0	<150	-	-
3390	0	<150	-	-
3463	0	<150	-	-
4302	500	475	- 25	- 5
4306	500	581	81	16
4326	500	484	- 16	- 3
5141	2670	2531	-139	- 5
5226	2670	2844	174	7
5249	2670	2500	-170	- 6
6080	5695	6000	305	5
6125	5695	5821	126	2
6345	5695	5786	91	2
7156	4240	4450	210	5
7222	4240	4200	- 40	- 1
7343	4240	3700	-540	- 13
8104	1735	2052	317	18
8155	1735	1958	223	13
8307	1735	2021	286	16
9220	745	833	88	12
9221	745	933	188	25
9222	745	858	133	15
Mean	2482	2587	109	15
Standard Deviation	2375	2405	223	32

TABLE 11. COMPARISONS OF EPA METHOD 6 AND EDC STACK ANALYZER MEASUREMENTS OF SO_2 IN STACK GAS

				Stack Concentration			
Run No. *	Date	Time	Plant Load (mw)	EPA Method 6 (ppm)	EDC Analyzer (ppm)	Difference (EDC-Method 6) (ppm)	Difference Over Method 6 (%)
6-1	11-15-77	1527-1612	241	495	450	-45	-9
6-3	11-16-77	1141-1211	240	472	450	-22	-5
6-5	11-16-77	1322-1352	242	488	470	-18	-4
6-7	11-16-77	1515-1545	240	483	460	-23	-5
6-9	11-17-77	1042-1112	239	452	440	-12	-3
6-11	11-17-77	1234-1304	240	474	450	-24	-5
6-12	11-17-77	1328-1358	239	466	460	- 6	-1
6-13	11-17-77	1413-1443	240	420	450	30	7
6-14	11-18-77	0844-0914	242	516	470	-46	-9
6-15	11-18-77	0921-0951	241	506	470	-36	-7
6-16	11-18-77	1023-1053	239	496	480	-16	-3
Mean			240	479	459	-20	-4
Standard Deviation			1	27	12	21	4

* Results for EPA Method 6 during runs 6-2, 6-4, 6-8, 6-10 produced obvious outline results believed due to a leak in the right angle probe-to-impinger connector.

TABLE 12. COMPARISONS OF THE EPA METHOD 7 AND EDC ANALYZER MEASUREMENTS OF NO IN STACK GAS

Run No.	Date	Time	Plant Load (mw)	Stack Concentrations		Difference (EDC-Method 6) (ppm)	Difference Over Method 6 (%)
				EPA Method 7 (ppm)	EDC Analyzer (ppm)		
7-1	11-15-77	1535	241	956	900	- 56	- 6
7-2	11-15-77	1550	241	982	890	- 92	- 9
7-3	11-15-77	1608	241	893	900	- 7	1
7-4	11-15-77	1623	241	965	900	- 65	- 7
7-5	11-15-77	1638	241	939	900	- 39	- 4
7-6	11-15-77	1655	241	1005	900	-105	-10
7-7	11-16-77	1015	239	1249	900	-349	-28
7-8	11-16-77	1045	239	927	880	- 47	- 5
7-9	11-16-77	1115	239	842	880	38	5
7-10	11-16-77	1145	240	828	890	- 62	7
7-11	11-16-77	1215	240	951	880	- 71	- 7
7-12	11-16-77	1245	240	976	890	- 86	- 9
7-13	11-16-77	1345	242	890	880	- 10	- 1
7-14	11-16-77	1415	242	918	880	- 38	- 4
7-15	11-16-77	1445	241	922	870	- 52	- 6
7-16	11-16-77	1515	241	900	860	- 40	- 4
7-17	11-16-77	1545	240	949	900	- 49	- 5
7-18	11-16-77	1615	240	952	900	- 52	- 5
7-19	11-17-77	1100	239	877	870	- 7	- 1
7-20	11-17-77	1130	240	920	880	- 40	- 4
7-21	11-17-77	1200	240	820	950	130	16
7-22	11-17-77	1230	240	858	840	- 18	- 2
7-23	11-17-77	1300	240	978	930	- 48	- 5
7-24	11-17-77	1330	239	910	930	20	2
7-25	11-17-77	1400	239	925	940	15	2
7-26	11-17-77	1430	240	1041	940	-101	-10
7-27	11-17-77	1500	240	950	950	0	0
7-28	11-17-77	1530	240	1031	960	- 71	- 7
7-29	11-17-77	1600	240	1009	950	- 59	- 6
7-30	11-17-77	1630	239	1051	940	-111	-11
7-31	11-18-77	0915	242	977	960	- 17	- 2
7-32	11-18-77	0930	241	975	970	- 5	- 1
7-33	11-18-77	0945	241	967	960	- 7	- 1
7-34	11-18-77	1000	241	1064	960	-104	-10
7-35	11-18-77	1015	241	1052	960	- 92	- 9
7-36	11-18-77	1030	239	1056	960	- 96	- 9
Mean			240	958	912	- 46	- 4
Standard Deviation			1	81	36	73	7

The EDC analyzer consistently underestimates the EPA Method 6 estimate by about 4% or 20 ppm. In view of the uncertainties and differences in the techniques of the two measurements, this small difference strongly supports the validity of the stack gas analyzer measurements.

Thirty-six comparisons were made for NO measurements. The EDC analyzer measurements showed a standard deviation of 36 ppm compared to a mean of 912 ppm or a 4% ratio of variability. The EPA Method 7 measurements showed a standard deviation of 81 ppm compared to a mean of 958 ppm or an 8% ratio of variability. The EDC measurements were consistently lower than the Method 7 measurements by an average of 46 ppm, which is about 5% of the Method 7 measurements. As with the SO_2, the NO measurements show very good agreement considering the differences and uncertainties in the two measurement techniques.

Overall, these results suggest that the NO and SO_2 measurements by the EDC gas analyzer are accurate to within 5% when the analyzer is working properly. Because of inherent differences in the two measurement techniques, it is not meaningful to estimate the accuracy of the EDC analyzer with any greater precision from the results of these tests.

Other significant measurements made during the stack gas analysis included the temperature, volume flow rate, oxygen content, CO_2 content and the NO_x/NO ratio. Exhaust gas temperature and velocity were determined in two exhaust gas profiles, each of which consisted of 48 traverse point samples from the breeching cross-section. The cross-section is 7.3 m high by 3.7 m wide. The average traverse temperatures were 392°K and 395°K compared to temperatures of 391°K and 394°K reported by the plant for the corresponding times. Based on these results, it is likely that the plant temperature records are within 1°K of what a traverse would determine the stack temperature to be.

The average traverse velocities were 14.8 and 14.4 m/sec. indicating volume flow rates of 397 and 385 m^3/sec respectively. These numbers compared to boiler air flow rates of 249.5 and 239.7m^3/sec reported by the plant for this same time period. The average ratio of air flow in the breeching to air flow in the boiler indicated by these measurements is 1.60. Accordingly, all boiler air flow measurements reported by the plant have been scaled by this ratio to estimate the stack gas flow rate.

Because of the large difference between the stack breeching measurements of air flow rate and the plant measurements of boiler air flow rate, a correlation was run between the boiler flow rate and generator load. The air flow, if it is meaningful, should be well correlated with the plant load. The correlation was 0.90. As a result, it was decided that the plant measurements multiplied by a factor of 1.60 are probably a good estimate of the stack gas exhaust flow rate. The scaled plant measurements are included in the hourly file of stack gas characteristics for each stack.

DATA FORMATS

The data collected in the field program has been organized on magnetic tape into the following six categories:

1. Fixed station data
2. Mobile ground station data
3. Helicopter data
4. Sulfate data
5. Plant operating data
6. Balloon data.

Each category of data is organized using a different format. A description of the format and the data items is presented for each of these types of data. All of the data files are available on magnetic tape in unlabeled, 1600 bpi, ASCII character format.

Fixed Station Data

The fixed station data is organized into a separate data file for each station. A separate record is entered in the file for each hour of recorded observations. The hour of the day indicated for each record refers to the 60 minute period ending at that whole hour. The record format is listed in Table 13. The table entries indicate the variable in each record, their order of appearance, a description of each variable including units, and the number and format of the characters (or numbers) for each variable. There are eight fixed station data files, one for each site. The following six-character codes designate each station:

Site	6-Character Code*
Tower	TOWERb
Munsey	MUNSEY
Nash's Ford	NASHSb
Hockey	HOCKEY
Castlewood	CASTLE
Johnson	JOHNSN
Lambert	LAMBER
Kent's Ridge	KENTSb

The following codes are used as flags:

W - Measurement is based on less than 22 scan values within the hour.

M - NO_2 calibration gas used to adjust instrument was not properly controlled. Measurement shows changes relative to other measurements within a few days, but may not be quantitatively correct.

S - Derived from strip chart.

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* b designates a blank character.

A - Arithmetic mean rather than vector mean of 2-minute scan values because wind speed or direction is missing.

L - Wind direction and speed are not reliable because wind speed is near or below the sensing threshold of the sensor.

E - Estimated zero applied to NO_x, NO data. Data is only qualitatively useful.

C - Incorrect zero/span values have been applied to data. Data is only qualitatively useful.

U - Data is uncalibrated (no zero/span applied). Data is only qualitatively useful.

N - NO_2 not computed since NO_x and NO are uncalibrated or calibrated incorrectly.

K - Kent's Ridge wind direction data unreliable.

Codes used to designate a missing or unacceptable measurement are listed in Table 13. Values are unacceptable if the instrument was malfunctioning and producing unuseful information. Incorrect data periods were determined by reviewing operating logs, records of calibration data and listings of the measurements.

Only one flag is assigned to each measurement. The following priorities are used to select a flag if more than one might be assigned:

Priority	Wind Speed	Wind Direction	Pollutant
1	L	K	N
2	A	A	M
3	W	W	E
4			U
5			C
6			S
7			W

Mobile Ground Station Data

Mobile Ground Monitoring data consists of data collected at different locations by the two mobile ground monitoring vans, designated Mobile 1 and Mobile 2. The data was originally recorded every 30 seconds as a voltage output on cassettes in the mobile units and then transcribed to 9 track ASCII reels. Each location sampled was identified by an event marker and time, which were also recorded on the cassette. The azimuth, distance and elevation of each location sampled were then abstracted from the operating log and merged with the data on tape using the time and event flag to match records.

Channels recorded are SO_2, for Mobile 2 and SO_2, NO_x, NO_2, NO, O_3, wind speed, wind direction and, temperature for Mobile 1. The channel data were converted to engineering units using the appropriate scale for each channel. Zero and span calibrations were applied using values taken before each run. The calibrated data was recorded on a file in the format

TABLE 13. FIXED STATION RECORD FORMAT ON MAGNETIC TAPE

Channel #	Variable Description	Column	Format*	Units	Missing**
	Station Code	1-6	A6	Code	
	Year	7-8	I2	Last Two Digits	
	Julian Day	9-11	I3	1-366	
	Hour of Day	12-13	I2	1-24	
	SO_2 Validity Flag	14-15	A2	Code	
1	Mean SO_2	16-20	F5.0	PPB by Volume	-999.
1A	Peak SO_2	21-25	F5.0	PPB by Volume	-999.
	NO_x Validity Flag	26-27	A2	Code	
2	Mean NO_x	28-32	F5.0	PPB by Volume	-999.
2A	Peak NO_x	33-37	F5.0	PPB by Volume	-999.
	NO_2 Validity Flag	38-39	A2	Code	
3	Mean NO_2	40-44	F5.0	PPB by Volume	-999.
3A	Peak NO_2	45-49	F5.0	PPB by Volume	-999.
	NO Validity Flag	50-51	A2	Code	
4	Mean NO	52-56	F5.0	PPB by Volume	-999.
4A	Peak NO	57-61	F5.0	PPB by Volume	-999.
	10 M Wind Speed Validity Flag	62-63	A2	Code	
5	10 M Wind Speed	64-68	F5.2	Meters per Second	999.
	10 M Wind Direction Flag	69-70	A2	Code	
6	10 M Wind Direction	71-75	F5.1	Degrees	999.
	10 M Sigma Azimuth Flag	76-77	A2	Code	
7	10 M Sigma Azimuth***	78-82	F5.1	Degrees	999.
	10M Temperature Validity Flag	83-84	A2	Code	
8	10M Temperature†	85-89	F5.1	Degrees C	999.
	UV Radiation Validity Flag	90-91	A2	Code	
9	UV Radiation	92-96	F5.2	Milliwatts per CM^2	999.
	Relative Humidity Flag	97-98	A2	Code	
10	Relative Humidity	99-103	F5.0	Percent	999.
	Precipitation Flag	104-105	A2	Code	
11	Precipitation	106-110	F5.2	Inches	999.
	10 M Wind Elevation Angle Flag	111-112	A2	Code	
12	10 M Wind Elevation Angle	113-117	F5.0	Degrees	999.
	10 M Sigma Elevation Flag	118-119	A2	Code	
13	10 M Sigma Elevation***	120-124	F5.1	Degrees	999.
	Lower Temperature Difference Flag	125-126	A2	Code	
14	0.5 to 4M Temperature Difference****	127-131	F5.1	Degrees C	999.
	30 M Wind Speed Flag	132-133	A2	Code	
15	30 M Wind Speed	134-138	F5.2	Meters per Second	999.

* All decimals implied

** A blank field indicates null channel

*** Sigma means the standard deviation of the two-minute scan values.

****Difference is upper level minus lower level

†Tower temperature at 4M

TABLE 13. (cont'd)

Channel #	Variable Description	Column	Format*	Units	Missing**
16	30 M Wind Direction Flag	139-140	A2	Code	
	30 M Wind Direction	141-145	F5.1	Degrees	999.
17	30 M Elevation Angle Flag	146-147	A2	Code	
	30 M Elevation Angle	148-152	F5.0	Degrees	999.
18	30 M Sigma Elevation Flag	153-154	A2	Code	
	30 M Sigma Elevation***	155-159	F5.1	Degrees	999.
19	Upper Temperature Difference Flag	160-161	A2	Code	
	0.5 to 30 M Temperature Difference****	162-166	F5.1	Degrees C	999.
20	30 M Sigma Azimuth Flag	167-168	A2	Code	
	30 M Sigma Azimuth***	169-173	F5.1	Degrees	999.
	Filler Character	174-176		Blank	

* All decimals implied.

** A blank field indicates null channel.

*** Sigma means the standard deviation of the two-minute scan values.

**** Difference is upper level minus lower level.

listed in Table 14. Records for both Mobile 1 and Mobile 2 data are 76 bytes long. Missing value indicators of -999 are used for all pollutants and meteorological data.

Each data record corresponds to an observation period. An event number and a corresponding location and time designate the beginning of the observation period. The measurements are mean or peak values observed between the beginning time and location and the ending time and location found in the following record (which designates the beginning time and location for the next observation period). The last record entered in the file for each mobile run contains all missing indicators and gives the ending location and time a corresponding event number.

The same editing procedures were used to identify missing and unacceptable values as were applied to the fixed station data.

Helicopter Data

Helicopter data were collected during two 10-d periods. The measurements were digitized and recorded on magnetic cassette tape while in flight. The data logger, which digitized and recorded data, scanned the sensing instruments in continuous cycles. The cycle frequency was generally between 4 and 5 times a second. The measurements of SO_2, NO and O_3 were also continuously recorded on strip charts. The strip charts and notes made by the observers during flight have been used to select those parts of the cassette tape records which have information relevant to the plume.

The sensing instruments produce an output voltage which is digitized and recorded on magnetic tape. The digital records were scaled to engineering units and corrected for nonlinearities in the output. All of the outputs are sufficiently close to being linear that deviations can be ignored, except for the relative humidity measurement. The response of that instrument will vary with the resistance sensor, which was changed each day. A mean response curve was derived by testing four elements. It was found that linear interpolation of the value listed in Table 16 reproduces the response of the tested elements with only a few percent error in the estimated relative humidity reading. As a result, this table was used to scale all the relative humidity readings. In addition, the following temperature correction was applied:

$$R = R_0 + \frac{1}{4R_0}(T - 25)(R_0 - 33)$$

R = relative humidity, percent.

R_0 = relative humidity measurement scaled by Table 16, percent.

T = ambient air temperature, °C.

Differences among relative humidity values above 95% are not significant, nor are differences below 20% significant, for the helicopter sensor.

TABLE 14. MOBILE GROUND STATION RECORD FORMAT FOR MAGNETIC TAPE

Variable	Position	Format	Description
UNIT	2-2	I1	Mobile unit # (1 or 2)
YEAR	4-5	I2	Last 2 digits of year (76 or 77)
JDAY	6-8	I3	Julian day
TIME	10-13	I4	Time of scan (Eastern Standard Time)
SEC	14-15	I2	Second of scan
FLAG	16-16	A1	A or P (indicating average or peak for the event
EVENT	17-19	I3	Event marker
EASTING	20-27	F8. 2	Easting distance from plant (decameters)
NORTHING	28-35	F8. 2	Northing distance from plant (decameters)
ELEV	36-40	I5	Elevation (ft above sea level) at start of event
SO_2	44-47	I4	SO_2 concentration (ppb)
NO_x	48-51	I4	NO_x concentration (ppb)
NO_2	52-55	I4	NO_2 concentration (ppb)
NO	56-59	I4	NO concentration (ppb)
O_3	60-63	I4	O_3 concentration (ppb)
WS	64-67	I4	Wind speed (mph)
WD	68-71	I4	Wind direction (degrees)
TEMP	72-75	I4	Temperature (°C)
	76		Blank

TABLE 15. HELICOPTER RECORD FORMAT FOR MAGNETIC TAPE

Variable	Position	Format	Description
UNIT	2-2	I1	Mobile Unit # (3)
YEAR	4-5	I2	Last 2 digits of year (76 or 77)
JDAY	6-8	I3	Julian day
TIME	10-13	I4	Time of scan (Eastern Standard Time)
SEC	14-15	I2	Second of scan
EVENT	17-19	I3	Event marker
EASTING	20-27	F8. 2	Easting distance from plant (decameters)
NORTHING	28-35	F8. 2	Northing distance from plant (decameters)
ELEV	36-40	I5	Elevation (ft above sea level) of helicopter
SO_2	44-47	I4	SO_2 concentration (ppb)
NO_x	48-51	I4	NO_x concentration (ppb)
NO_2	52-55	I4	NO_2 concentration (ppb)
NO	56-59	I4	NO concentration (ppb)
O_3	60-63	I4	O_3 concentration (ppb)
RH	64-67	I4	Relative humidity (%)
	68-83		Blank
TEMP	84-87	I4	Temperature (°C)
	88		Blank

TABLE 16. LINEAR INTERPOLATION TABLE FOR RELATIVE HUMIDITY MEASUREMENTS

Recorded Voltage	Relative Humidity, Percent*
< 0.5	Reject
0.5	21
0.8	47
1.0	53
1.5	65
2.0	72
3.0	82
5.0	100
> 5.0	Reject

* Uncorrected for temperature influence (see text).

The record format of the helicopter is listed in Table 15. There are 16 files of records covering the two 10-d observation periods. Each record corresponds to a set of readings made during a single cycle of the data logger. The data were also edited using the same procedures to identify unaccpetable data as were applied to fixed station data. Record lengths of 88 bytes are used. Missing value indicators of -999 are used for the pollutants and relative humidity data. Any negative number can be considered missing for the temperature data.

Sulfate Data

Sulfate measurements consist of particulate matter analyzed for sulfate content collected on filters at any of six fixed stations (there were only five samplers, but one was moved) or in the Mobile 1 van. The net amount of sulfate collected as airborne aerosol during a 1-hour sampling period must be estimated from the sulfate content measured by laboratory analysis by corrections for several interferences, including:

- Sulfate content of filter material
- Sulfate accumulated during nonsampling exposure to the air and during transport and handling
- SO_2 absorbed during sampling which is converted to sulfate prior to analysis.

The sulfate content of the filter material is determined by submitting blanks which are not exposed in the field to analysis and determining the average value of the filter sulfate content. The accumulated sulfate is determined by submitting one filter out of every 24 to the same exposure treatment as sample filters, including mounting on a hi-vol sampling head, except that no sample air is drawn through the filter. The sulfate content of the exposed blank is a measure of the accumulated sulfate. The amount of absorbed SO_2 transformed to sulfate has not been identified. However, the SO_2 concentration when the sample was taken is known, and the field conditions in terms of temperature and relative humidity can be reconstructed. When more is known about this mechanism, it may be possible to correct for this effect.

A strip chart record of the average air flow rate during a sulfate sampling hour is manually interpreted and recorded as is the duration of the sample (which may be a minute or so more or less than an hour). The net sulfate on a filter, corrected for filter sulfate, and accumulated nonsample sulfate, divided by the air flow rate times the sample time, is the measured sulfate concentration. Table 17 lists the record and character formats used to store the sulfate data on magnetic tape. The time designates when the sample was started. All of the data records are entered in one data file with all of the records for a single station grouped together in chronological order. The stations are identified by the following two character codes and appear in the following order in the data file:

Station	Code
Castlewood	CA
Hockey	HO
Johnson	JO
Kent's Ridge	KE
Munsey	MU
Nash's Ford	NA
Mobile 1 Van	MO

TABLE 17. SULFATE RECORD FORMAT FOR MAGNETIC TAPE

Variable	Record Position	Character Format	Units
Station Name	1-2	A2	Code
Year	3-4	I2	76 or 77
Month	5-6	I2	1 to 12
Day of Month	7-8	I2	1 to 31
Hour of Day	9-10	I2	0 to 24 (Eastern Standard)
Minute of Hour	11-12	I2	0 to 59
Filter Number	13-16	I4	1 to 9999
Net Sulfate Corrected	17-20	I4	Micrograms
Sampled Air Volume	21-25	F5.1	Cubic meters
Sulfate Concentration	26-30	F5.1	Micrograms per cubic meter
Elevation	31-34	I4	Meters above mean sea level (mobile unit only)
Distance from Plant	35-38	F4.1	Kilometers (mobile unit only)
Direction from Plant	39-42	I4	Degrees (mobile unit only)
	43-44		Blank

Plant Operating Data

The plant operating data includes hourly measurements of the plant's exhaust gases and operating characteristics plus the plant's weekly determinations of heat conversion efficiency, fuel heat content and fuel sulfur content. The basic information is used to generate daily and hourly records of plant data which are stored in the format shown in Table 18. A single data file containing, for each day during the monitoring period, a daily header and 24 hourly records was formed and is available on magnetic tape.

Each of the information items in Table 18 was generated in a consistent manner. The daily sulfur content is a 7-d running average of measurements made by the plant on samples drawn from coal shipments as they are received. Each shipment is dumped into a storage pile, where it is mixed with successive shipments on a daily basis. The 7-d averaging time was found to be the best measure of sulfur content of fuel burned when compared with measurements of SO_2 concentrations in the flue gas.

The heat content of the fuel and the heat conversion rate of each boiler-generator combination is determined on a weekly basis for the fuel fed to each boiler. These numbers are very stable on a week-to-week basis as well as between boilers. No adjustments are made on a daily basis to the plant's weekly estimates.

The temperature of the exhaust gas from each boiler is measured in the breeching leading to the stack. The temperature, reported by the plant in °F, is converted to °K.

Although the exhaust temperature is measured, the exhaust flow rate is not measured. The air flow into each boiler and the oxygen content in the air as it leaves each boiler are measured. The mass of the exhaust gas is considerably greater than the sum of the fuel plus the intake air due primarily to the leakage of additional air into the system. The ratio of exhaust flow to intake flow has been measured in a few instances giving the results listed in Table 19. The intake air flow rates reported in the data records has been scaled to a reasonable estimate of exhaust flow rates using the average ratio of exhaust to intake flow rates for each unit.

The hourly generator loads are included in the data set because they are the best available measure of hourly variations in fuel consumption and pollutant emission rates. These values are entered as received from the plant's records.

The remaining numbers in the data record are the measured and estimated rates of SO_2 and NO emissions. The measured emission rates are the measured stack concentrations converted to a mass flow rate based on the exhaust gas volume flow rate.

TABLE 18. PLANT OPERATING CHARACTERISTIC RECORD FORMAT FOR MAGNETIC TAPE

	Record Position	Character Format	
Daily Header Record:			
Year	1-2	I2	76 or 77
Month of Year	3-4	I2	1 to 12
Day of Month	5-6	I2	1 to 31
Sulfur Content of Fuel	7-10	F4.2	Percent
Fuel Heat Content, Unit #1	11-15	I5	BTU per pound
Heat Rate, Unit #1	16-20	I5	BTU per kilowatt-hour
Fuel Heat Content, Unit #2	21-25	I5	BTU per pound
Heat Rate, Unit #2	26-30	I5	BTU per kilowatt-hour
Fuel Heat Content, Unit #3	31-35	I5	BTU per pound
Heat Rate, Unit #3	36-40	I5	BTU per kilowatt-hour
	41-76		Blank
Hourly Records			
Stack Temperature, Unit #1	1-3	I3	Degrees Kelvin
Air Exhaust Rate, Unit #1	4-6	I3	Cubic meters per second
Net Generator Load, Unit #1	7-9	I3	Megawatts
Theoretical SO_2 Emission Rate, #1	10-12	I3	Grams per second
Estimated SO_2 Emission Rate, #1	13-15	I3	Grams per second
Theoretical NO Emission Rate, #1	16-18	I3	Grams per second
Estimated NO Emission Rate, #1	19-21	I3	Grams per second
Stack Temperature, Unit #2	22-24	I3	Degrees Kelvin
Air Exhaust Rate, Unit #2	25-27	I3	Cubic meters per second
Net Generator Load, Unit #2	28-30	I3	Megawatts
Theoretical SO_2 Emission Rate, #2	31-33	I3	Grams per second
Estimated SO_2 Emission Rate, #2	34-36	I3	Grams per second
Theoretical NO Emission Rate, #2	37-39	I3	Grams per second
Estimated NO Emission Rate, #2	40-42	I3	Grams per second
Stack Temperature, Unit #3	43-45	I3	Degrees Kelvin
Air Exhaust Rate, Unit #3	46-48	I3	Cubic meters per second
Net Generator Load, Unit #3	49-51	I3	Megawatts
Theoretical SO_2 Emission Rate, #3	52-54	I3	Grams per second
Measured SO_2 Emission Rate, #3	55-57	I3	Grams per second
Estimated SO_2 Emission Rate, #3	58-60	I3	Grams per second
Theoretical NO Emission Rate, #3	61-63	I3	Grams per second
Measured NO Emission Rate, #3	64-66	I3	Grams per second
Estimated NO Emission Rate, #3	67-69	I3	Grams per second
Barometric Pressure at Plant	70-74	F5.2	In. of mercury
	75-76		Blank

TABLE 19. CORRESPONDING MEASUREMENTS OF BOILER INTAKE AND STACK EXHAUST GAS FLOW RATES

Unit Number	Intake Air (m^3/sec)	Exhaust Air (m^3/sec)	Ratio
1	266.41	384.64	1.444
1	268.58	395.15	1.471
mean			1.458
2	252.63	387.96	1.536
2	252.32	396.10	1.570
mean			1.553
3	252.15	390.27	1.548
3	252.15	390.27	1.548
3	253.79	388.17	1.529
3	250.66	380.17	1.519
3	253.04	381.48	1.508
3	247.22	373.57	1.511
3	266.32	397.42	1.492
3	238.72	385.15	1.613
3	253.64	363.44	1.433
mean			1.522

SO_2 Emissions

Theoretical SO_2 emission estimates were calculated by the following equation:

$$Q = \frac{G \times K \times S \times F}{H}$$

where

Q = stack emission rate, g/sec

G = rate of output by generators, kw

K = thermal conversion rate of boiler/generator units, BTU/kw sec

S = sulfur content of fuel, mass ratio (dimensionless)

F = 1.9 = sulfur dioxide emissions per unit of fuel sulfur, mass ratio (dimensionless)

H = heat content of fuel, BTU/g.

The thermal conversion rate (K) was computed by the plant for each generator/boiler unit each week. These estimates for the three generators were furnished to us by the plant.

In order to estimate SO_2 emission rates from units 1 and 2, a multiple linear correlation and regression analysis was performed using the measured hourly average SO_2 emission rates for Unit #3, the generator load data, and the sulfur content data. When the SO_2 emission rate was treated as the dependent variable and the load and sulfur content were as independent variables, the best correlation was obtained when the analysis was limited to the range of SO_2 emission rates from 75g/sec to 550g/sec and 14 d of suspicious monitoring data were eliminated from the analysis. The following regression formula was obtained:

$$Q_{SO_2} = 485.372\ PSULF + 1.185\ G - 331.007$$

where PSULF is the percent sulfur content of the coal. The multiple correlation coefficient between the SO_2 emission rate and the independent variables PSULF and G is 0.72 and the standard error of estimate is 57.9g/sec.

For typical Clinch River Plant conditions of PSULF = 0.8%, G = 200 MW, K = 9,200 BTu/KW-hr, and H = 12,000 BTu/lb., the regression formula yields an SO_2 emission rate of 294.3 g/sec, while the EPA emission factor from AP-42 yields 293.9g/sec.

Higher correlations are obtained when the theoretically computed mass of SO_2 emitted on a weekly basis is compared to the total measured SO_2 emitted over a week. Using 30 weeks of these comparisons a linear correlation coefficient of 0.92 was obtained.

The 14 d of suspicious SO_2 stack monitoring data still remain on the plant data file since the data are qualitatively useful despite the stack monitor being out of calibration. The measured SO_2 emission rates on these days are higher than the typical rates. The dates are as follows:

January 16, 17, 1977
March 21, 22, 1977
June 24, 25, 1977
July 25, 26, 27, 1977
August 2, 3, 1977
August 10, 11, 1977
August 16, 1977

NO Emissions

Theoretical NO emission estimates were calculated by the following equation:

$$Q = \frac{E \times G \times K}{H}$$

where

$E = 5.87 \times 10^{-3}$ = NO emissions per unit of fuel, mass ratio (dimensionless).

The emission factor (E) is based on the NO molar equivalent to 9 kg of NO_2 per m ton of bituminous coal for a dry bottom, pulverized coal furnace as given in EPA document AP-42, "Compilation of Air Pollution Emission Factors".

In order to estimate NO emissions from units 1 and 2, linear regression analysis was also performed on the hourly average NO-measured emission rates for Unit #3 and the generator load data. When NO was treated as the dependent variable and the generator load as the independent variable the following regression formula was obtained:

$$Q_{NO} = 1.103G - 33.152$$

Fifty-one days of suspicious NO monitoring data were not considered in the analysis used to form this equation. A linear correlation coefficient of 0.68 and a standard error of estimate of 44.7g/sec were obtained.

The monitored NO emission rates from the 51 days still remain on the plant data file since the data is qualitatively useful despite the readings being high compared with typical NO emission rates. These periods generally began a few days prior to the periodic calibration of the stack monitor by Environmental Data Corporation. The dates are as follows:

December 29, 1976 - January 15, 1977
February 2, 1977 - February 4, 1977
March 1, 1977 - March 15, 1977
May 26, 1977 - June 9, 1977

For typical Clinch River Plant conditions of G = 200 MW, K = 9,200 BTu/KW-hr and H = 12,000 BTu/lb., the regression formula yields an NO emission rate of 187.4g/sec. When the emission factor (E) is used with these same conditions, an NO emission rate of 113.5g/sec is obtained.

Balloon Data

This data consists of reductions of double and single theodolite observations of pibal releases, some with associated temperature-sondes, to give vertical profiles of wind speed, wind direction, and temperature. Ground-level readings of wet and dry bulb temperatures and relative humidity were taken with some of the releases and are also included. Releases are identified by Gregorian Date and Eastern Standard Time.

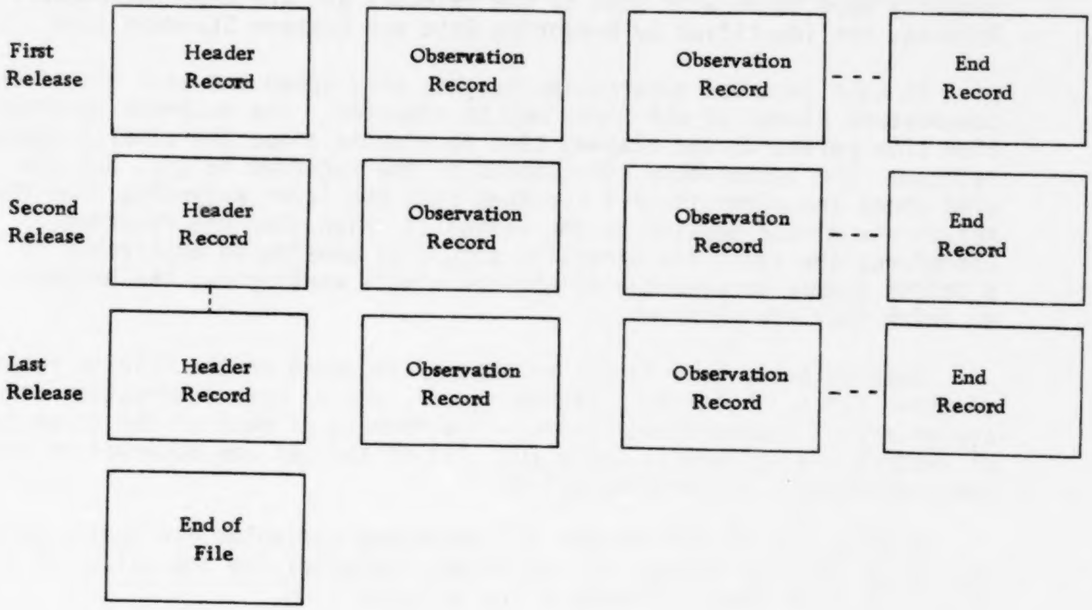
At each recorded observation height, wind speed and wind direction or temperature alone, or all three may be reported. The recorded observation time refers to the elapsed time in minutes since the pibal/t-sonde release. The temperature corresponds to the recorded height, but the wind speed and direction are averages over the layer extending from the height one minute earlier to the height at which they are recorded. Therefore, the speed and direction should be considered applicable to a height midway between the height one minute earlier and the height at which they are recorded.

Data relating to a single release is recorded on the file in records of three types, including a header record, one or more observation records and an end of observations record. The formats of each of the three types of records are defined in Table 20. All of the balloon observation records are contained in a single data file.

Missing values for integer (I) character variables are indicated by the value -99; for decimal (F) character variables, by the value -99.9. It may be noted that all records are 32 bytes long.

TABLE 20. BALLOON DATA RECORD FORMAT FOR MAGNETIC TAPE

a. File Organization


First Release
Header Record
Observation Record
Observation Record
End Record
Second Release
Header Record
Observation Record
Observation Record
End Record
Last Release
Header Record
Observation Record
Observation Record
End Record
End of File

b. Header Record Format

Variable	Record Position	Character Format	Units	Missing Indicator
Year	1-2	I2	76-77	
Month of Year	3-4	I2	1 to 12	
Day of Month	5-6	I2	1 to 31	
Release Time	7-10	I4	Eastern standard time	
Type of Record	11-11	I1	"1"	
Baseline	12-13	A2	Code (see Section 4)	
Relative Humidity, Ground Level	14-16	I3	Percent	-99
Dry Bulb Temperature, Ground Level	17-21	F5. 1	Degrees centigrade	-99. 9
Wet Bulb Temperature, Ground Level	22-26	F5. 1	Degrees centigrade	-99. 9
Blank	27-32			

(continued)

c. Observation Record Format

Variable	Record Position	Character Format	Units	Missing Indicator
Year	1-2	I2	76-77	
Month of Year	3-4	I2	1 to 12	
Day of Month	5-6	I2	1 to 31	
Release Time	7-10	I4	Eastern standard time	
Type of Record	11-11	I1	"2"	
Observation Time (end)	12-15	F4-1	Minutes	
Height (at observation time)	16-19	I4	Meters	
Wind Speed (average)*	20-22	I3	Meters per second	-99
Wind Direction (average)*	23-25	I3	Degrees	-99
Temperature (at observation time)	26-30	F5-1	Degrees centigrade	-99.9
	31-32		Blank	

d. End of Record Format

Variable	Position	Character Format	Units
Year	1-2	I2	76-77
Month of Year	3-4	I2	1 to 12
Day of Month	5-6	I2	1 to 31
Time	7-10	I4	Eastern standard time
Type	11-11	I1	"3"
Blank	12-32		Blank

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*Averaged over 1-minute layer below this observation height.

SECTION 6

PROJECT CHRONOLOGY

CALENDAR OF EVENTS

Table 21 presents a chronological list of events which describe significant field events. These are intended as a guide in interpreting the data collected during the field project. Major changes in the observing capability of this sytem are noted and causes for the change are cited. Also noted are events which may increase or decrease the degree of confidence associated with the data.

TABLE 21. CHRONOLOGY OF SIGNIFICANT FIELD EVENTS

Date	Event
June 1, 1976	Start of field data collection. Valid data being recorded from the Tower, Munsey and Nash's Ford monitoring sites via telemetering to the central facility.
June 2, 1976	First pilot balloon measurements taken.
June 3, 1976	First run made with mobile van.
June 17, 1976	Valid data being recorded from Hockey site via telemetering to the central facility.
June 24, 1976	Valid data being recorded from Castlewood site via telemetering to the central facility.
July 1, 1976	Valid digitized data being recorded from Kent's Ridge site via onsite cassette tape recorder.
July 28, 1976	Test run with helicopter over Bristol.
July 29, 1976	Tower site struck by lightning and no valid data recorded until August 20.
August 16, 1976	Began recording 30 m wind speed and wind direction at Hockey site.
August 20, 1976	Valid SO_2 data from Tower being recorded on strip chart.
August 23, 1976	Hi-vol samplers begin collection for sulfates at Munsey, Nash's Ford, Hockey and Castlewood sites.
August 24, 1976	Valid data from Tower site being telemetered to central facility.
September 8, 1976	Full complement of meteorological measurements restored to operation at Tower site.
September 14, 1976	Telephone line installed and DAS operating at Kent's Ridge. Cable failure at Tower site reduced meteorological data to 1 level.
September 18, 1976	Johnson SO_2 data recorded on strip chart (only until September 24).
September 29, 1976	Helicopter sampling with power plant precipitators shut down.
October 3, 1976	Helicopter sampling with power plant precipitators shut down.
October 5, 1976	Began taking T-Sondes.

(continued)

TABLE 21. (continued)

Date	Event
October 8, 1976	Approximately $3\frac{1}{2}$" of rainfall measured in 24-hour period.
October 11, 1976	All stations taken off auto zero/span.
October 20, 1976	Power plant unit #2 is down for repair, 4 weeks.
October 21, 1976	Computer is down until October 26.
October 24, 1976	Lower level wind speed sensor installed at Hockey site.
October 26, 1976	Computer back in service.
October 27, 1976	Lambert site put on-line.
November 4, 1976	In-stack monitor put in service.
November 7, 1976	Began converting the NO calibration methodology to provide a more stable calibration gas.
November 8, 1976	Helicopter sampling.
November 9, 1976	Helicopter sampling.
November 10, 1976	Helicopter sampling.
November 11, 1976	Helicopter sampling.
November 14, 1976	Full complement of meteorological sensors back in operation at Tower site.
November 15, 1976	Service "A" circuit discontinued.
November 16, 1976	Helicopter sampling.
November 17, 1976	Helicopter sampling; Johnson site on line.
November 18, 1976	All 8440 monitors now operating with stable calibration gas.
November 24, 1976	Service "C" circuit discontinued.
December 10, 1976	Hi-Vol sampler from Munsey site installed at Johnson site.
December 19, 1976	Stack monitor NO channel put in service by EDC; recorded on strip chart.
December 30, 1976	Received long-range antenna for T-Sonde receiver.

(continued)

TABLE 21. (continued)

Date	Event
January 20, 1977	Changed ADAM System magnetic tape format.
January 20 - 21, 1977	RTI System Audit.
January 31, 1977	1) Second blazer obtained for use in field operations; 2) sent T-Sonde receiver to Contel for repairs.
February 9, 1977	Mobile 1 portable generator taken in for major repairs. Repairs not completed until March 7 due to lack of parts.
February 11, 1977	Received repaired T-Sonde receiver.
February 15 - 23, 1977	RTI Performance Audit.
March 5, 1977	Purchased back-up portable generator for Mobile 1.
March 7, 1977	Original Mobile 1 portable generator repaired and returned to field.
March 18, 1977	Attempts at using second surface mobile sampling unit aborted. Vehicle and personnel involved were switched to intensified upper air program.
March 22, 1977	Received EPA Radiosonde equipment at the field site.
March 24, 1977	Received and installed microbarograph at the field office.
March 30, 1977	Field personnel constructed T-Sonde antenna mount for the theodolite. T-Sonde/Pibal program thus reduced from 3 to 2 people.
April 3, 1977	Heavy rains began in late afternoon.
April 4, 1977	Continued heavy rains. Severe water leak in trailer roof at Tower site, but no damage to instruments.
April 5, 1977	Heavy flooding in Southwest Virginia. Castlewood trailer destroyed by flood waters from Clinch River. Power plant shut down all boilers. Moss #3 coal cleaning plant shut down. Stack monitor damaged.
April 6, 1977	Began recovery operations for Castlewood equipment.
April 8, 1977	Moss #3 coal cleaning plant back in operation.

(continued)

TABLE 21. (continued)

Date	Event
April 13, 1977	Power plant Unit #3 fired up and brought on line.
April 15, 1977	Stack monitor NO channel repaired. SO_2 channel still not operable.
April 17, 1977	Power plant Unit #1 fired up and brought on line.
April 20, 1977	Power plant Unit #2 fired up and brought on line.
May 31, 1977	Installed new style ozone generating unit in Tower NO_x analyzer.
June 6, 1977	Severe thunderstorm, knocking out power to all stations but Lambert. Hockey power off until June 9, 1977. Only damage was to upper level wind sensor and Tower site.
June 9, 1977	Calibrate wind speed sensors at Johnson and Munsey sites.
June 10, 1977	Unit #3 shut down; calibrate wind speed sensors at Hockey, Kent's Ridge, and Lambert sites.
June 11, 1977	Calibration of wind speed sensors at Lambert (again), Nash's, and Tower.
June 13, 1977	Change in output parameterization for stack monitor; voltages are halved to both recorder and ADAM system; unit #3 back in service.
June 15, 1977	Stack monitor now fully operational.
June 16, 1977	EDC checked stack monitor output; found it to be OK; recorder still faulty. Discovery of broken prop on upper level vector vane at Tower site.
June 18, 1977	Stack monitor giving constant output on both (SO_2 and NO) channels.
June 22, 1977	Stack minotor and recorder now operational (1922 EST).
June 24, 1977	Adjusted zero offset of SO_2 channel for stack monitor's recorder to 300 ppm; output to ADAM system unaffected.
June 25, 1977	Intercomparative calibration check at Munsey site: on-site calibrator vs. mobile calibrator for SO_2, NO_x, NO_2, NO analyzers.
June 26, 1977	Intercomparative calibration check at Lambert site: on-site calibrator vs. mobile calibrator for SO_2 analyzer.
June 30, 1977	Unique plume encounter at Hockey site--off-scale measures of SO_2, NO_x, 0348-0442 EST, with no effect at Munsey.

(continued)

TABLE 21. (continued)

Date	Event
July 5, 1977	Adjustment to NO dilution flow in Kent's Ridge calibrator.
July 6, 1977	Power failure at stack monitor.
July 7, 1977	Adjustment to NO dilution flow in Munsey's calibrator.
July 10, 1977	Lightning strike at Tower site disabling SO_2 analyzer and most equipment as well as data logger. NO_x on strip chart only.
July 12, 1977	Performance audit (informal) at Munsey site. Stack monitor returned to service.
July 15, 1977	Lambert trailer installed at Castlewood site; Tower site less meteorological data, NO_2, NO.
July 18, 1977	Begin intensive phase with helicopter sampling.
July 29, 1977	End intensive phase.
August 1, 1977	Adjustment to NO dilution in Nash's Ford calibrator.
August 2, 1977	Adjustment to NO dilution in Tower calibrator.
August 5, 1977	Begin performance audit.
August 12, 1977	End performance audit.
August 16, 1977	Install new style O_3 generators in Munsey; Nash's Ford NO_x analyzers analyzers.
August 17, 1977	Install new style O_3 generator in Kent's Ridge NO_x analyzer.
August 20, 1977	Unit #3 shut down until after end of project.
August 22, 1977	Castlewood site has power.
August 25, 1977	First data from Castlewood since flood - wind direction on strip chart.
August 28, 1977	Castlewood site returned to ADAM system - meteorological data only.
September 1, 1977	Castlewood reporting SO_2 as well as meteorological data.
September 9, 1977	Reallign lower wind direction sensor at Hockey.
September 30, 1977	Final day of formal data collection.

Section 7

References

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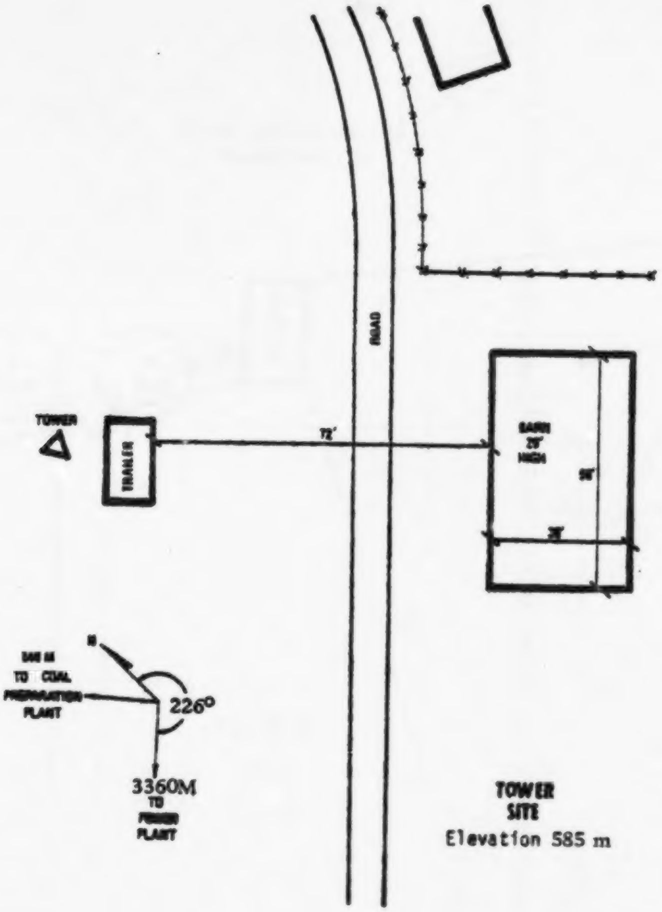
Engineering Science. 1978. EPA Reference Method Measurements of Emissions from Clinch River Power Plant. EPA Contract No. 68-02-2815. Engineering Science, McLean, VA.

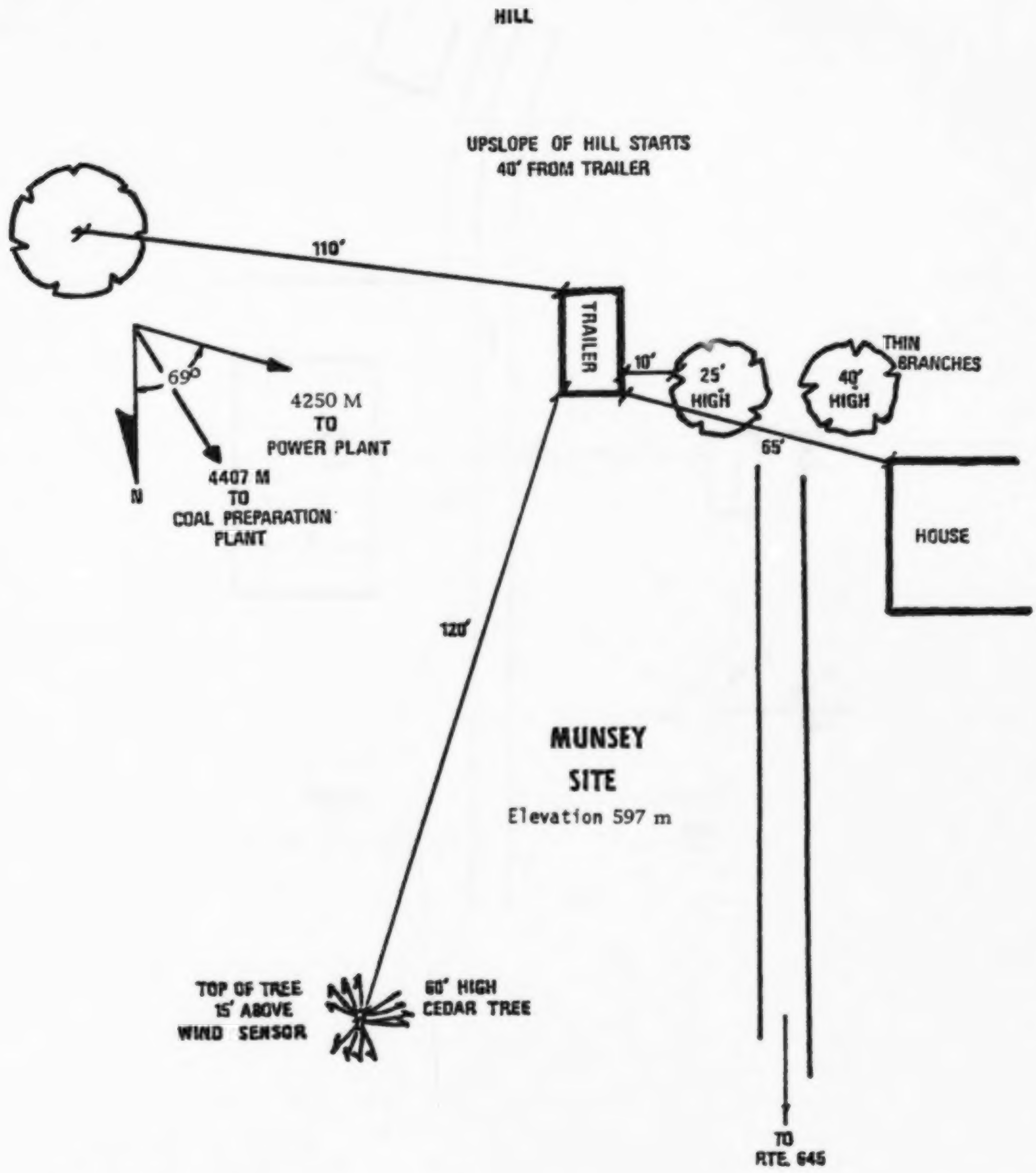
Holzworth, G. C. 1972. "Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States," Environmental Protection Agency, AP-101. Research Triangle Park, North Carolina.

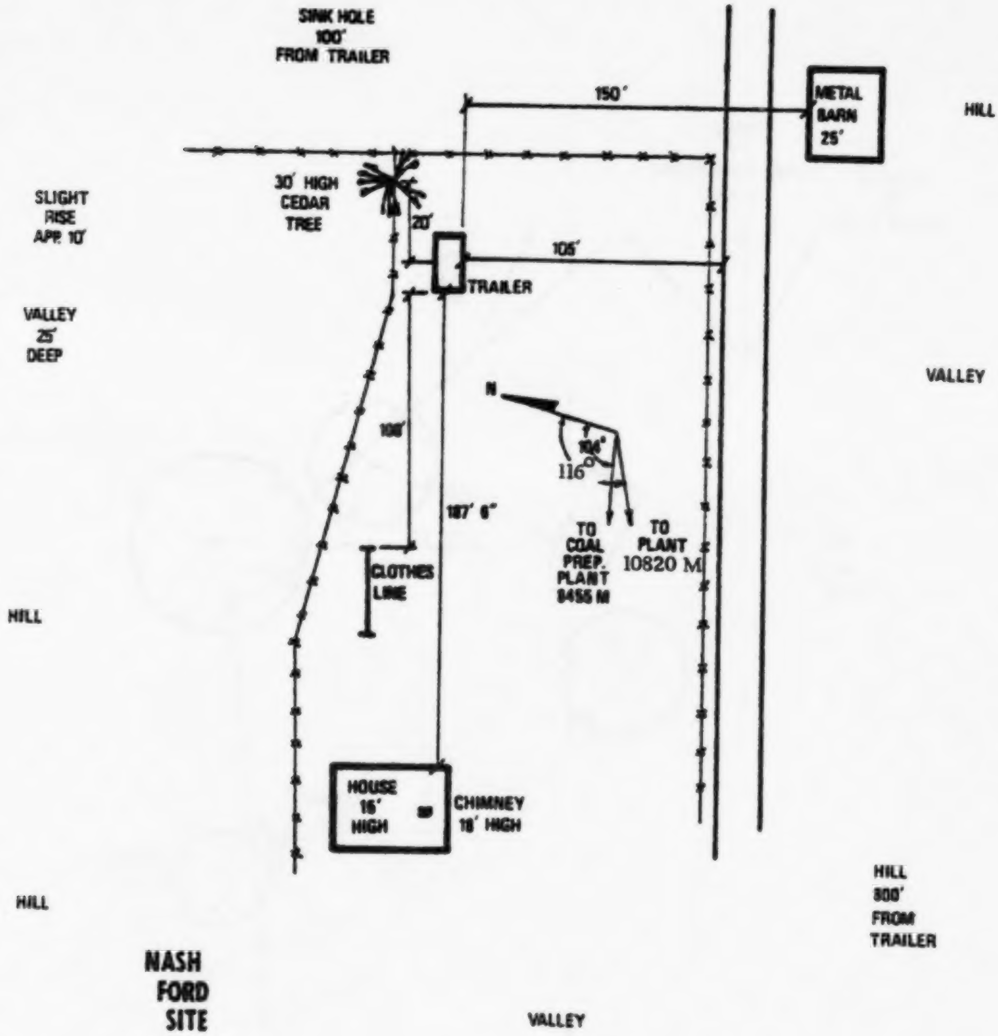
APPENDIX A

SITE LAYOUT DIAGRAMS FOR EIGHT FIXED MONITORING STATIONS


TOWER
TRAILER
72'
ROAD
BARN
29'
HIGH
N
M
TO COAL
PREPARATION
PLANT
226°
3360M
TO
POWER
PLANT

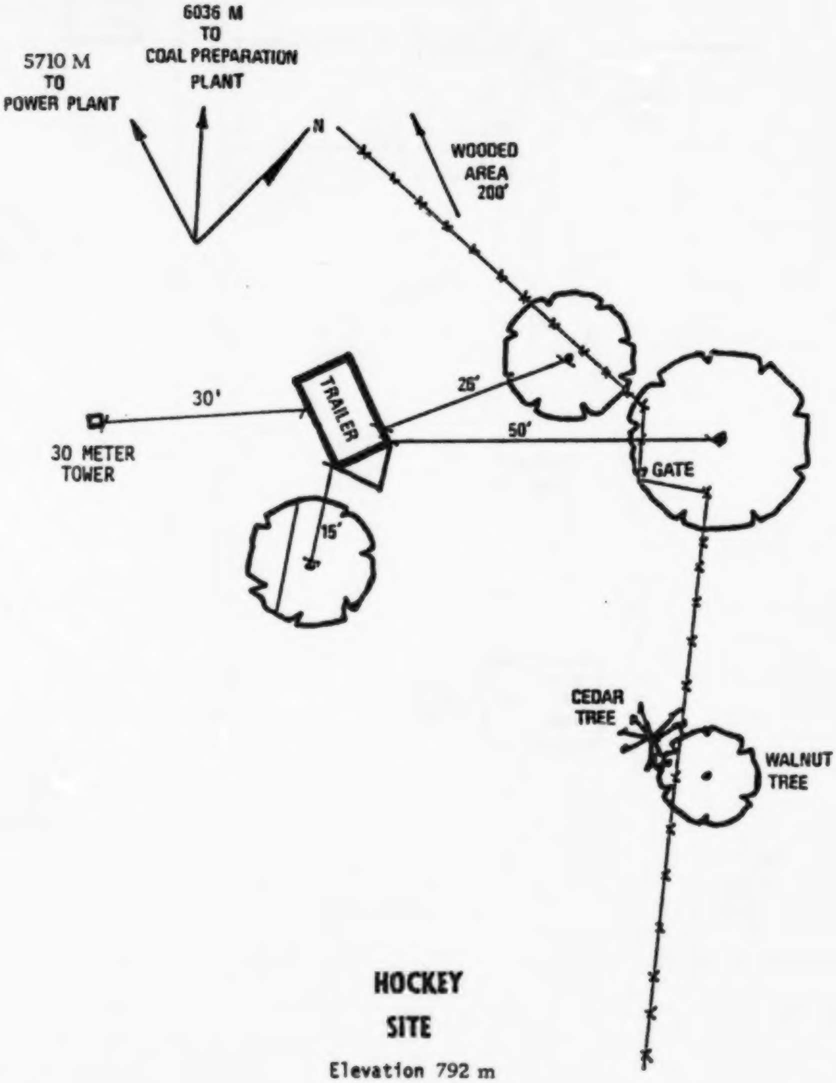
TOWER SITE
Elevation 585 m


HILL
UPSLOPE OF HILL STARTS 40' FROM TRAILER
110'
TRAILER
10'
25' HIGH
40' HIGH
THIN BRANCHES
65'
HOUSE
69°
4250 M TO POWER PLANT
4407 M TO COAL PREPARATION PLANT
N
120'
MUNSEY SITE
Elevation 597 m
TOP OF TREE 15' ABOVE WIND SENSOR
60' HIGH CEDAR TREE
TO RTE. 645


SINK HOLE
100'
FROM TRAILER
150'
METAL
BARN
25'
HILL
30' HIGH
CEDAR
TREE
SLIGHT
RISE
APP. 10'
20'
105'
TRAILER
VALLEY
25'
DEEP
VALLEY
N
106°
116°
108'
187' 6"
TO
COAL
PREP.
PLANT
9455 M
TO
PLANT
10820 M
CLOTHES
LINE
HILL
HOUSE
15'
HIGH
CHIMNEY
18' HIGH
HILL
300'
FROM
TRAILER
HILL
VALLEY

NASH
FORD
SITE

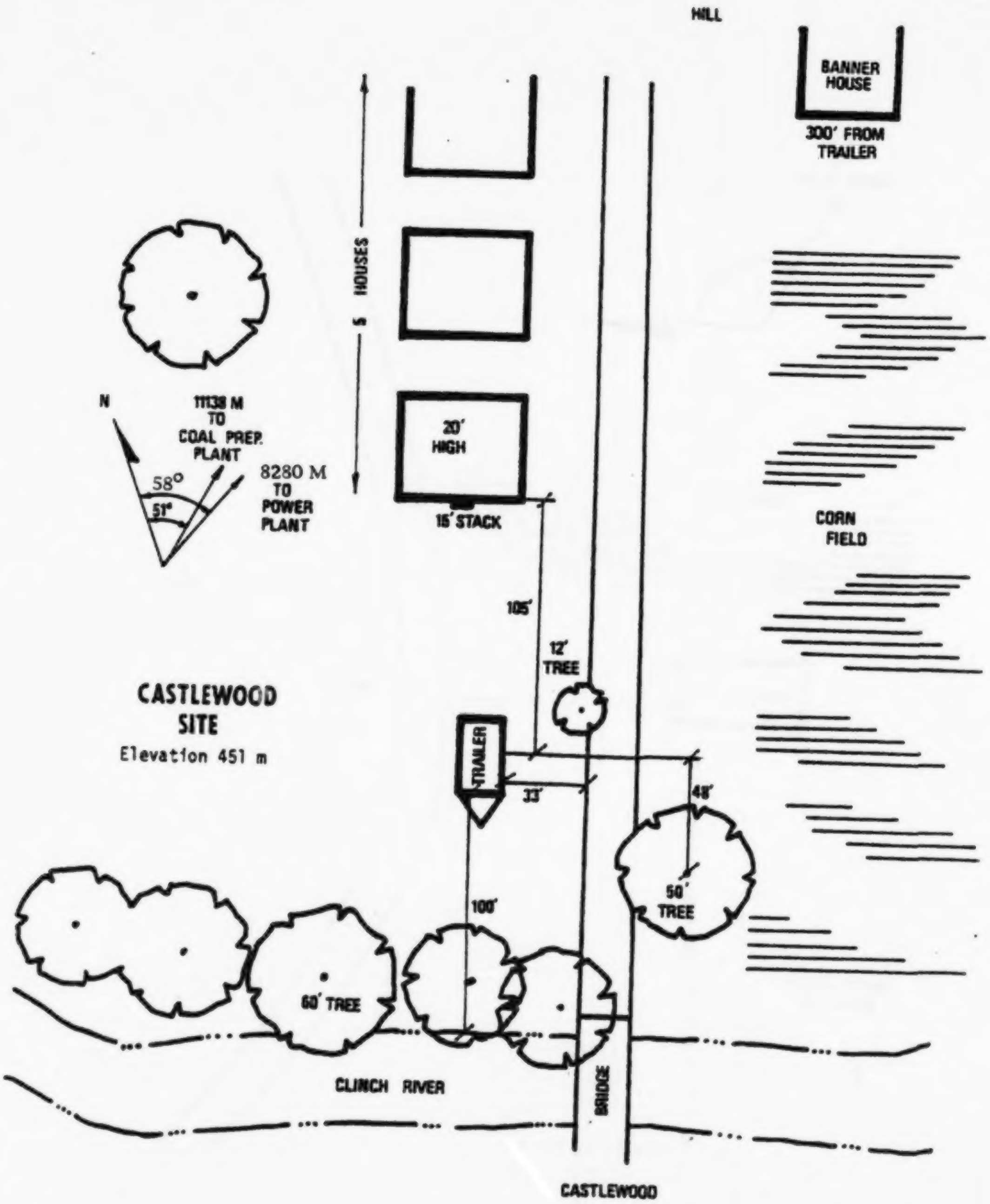
Elevation 567 m


6036 M
TO
COAL PREPARATION
PLANT
5710 M
TO
POWER PLANT
N
WOODED
AREA
200'
30'
26'
50'
TRAILER
30 METER
TOWER
15'
GATE
CEDAR
TREE
WALNUT
TREE

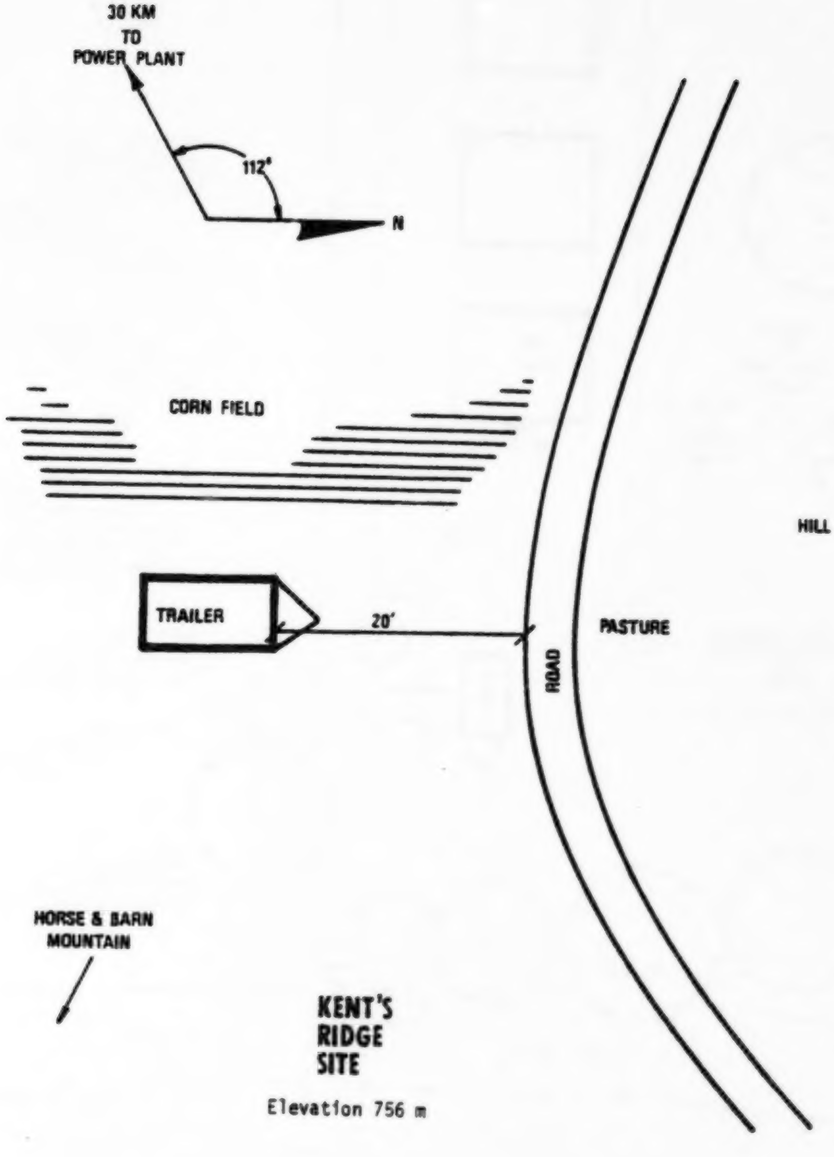
HOCKEY

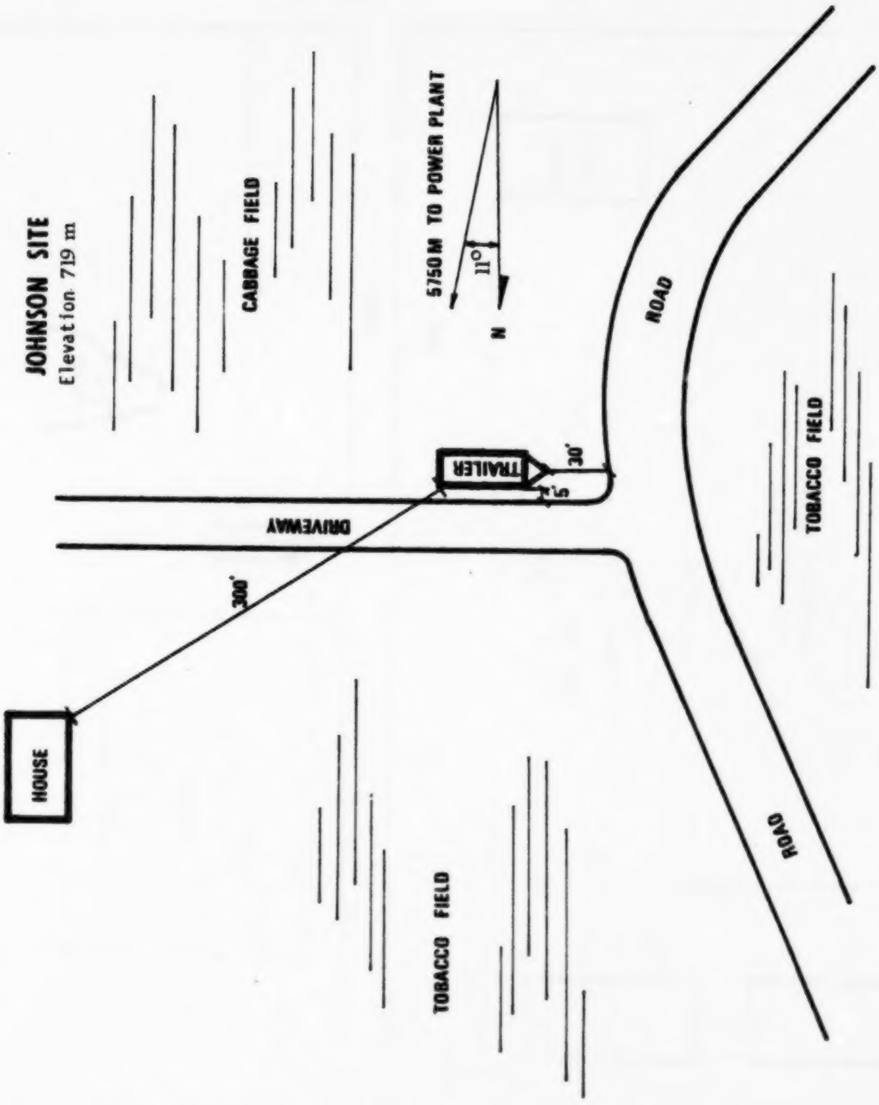
SITE

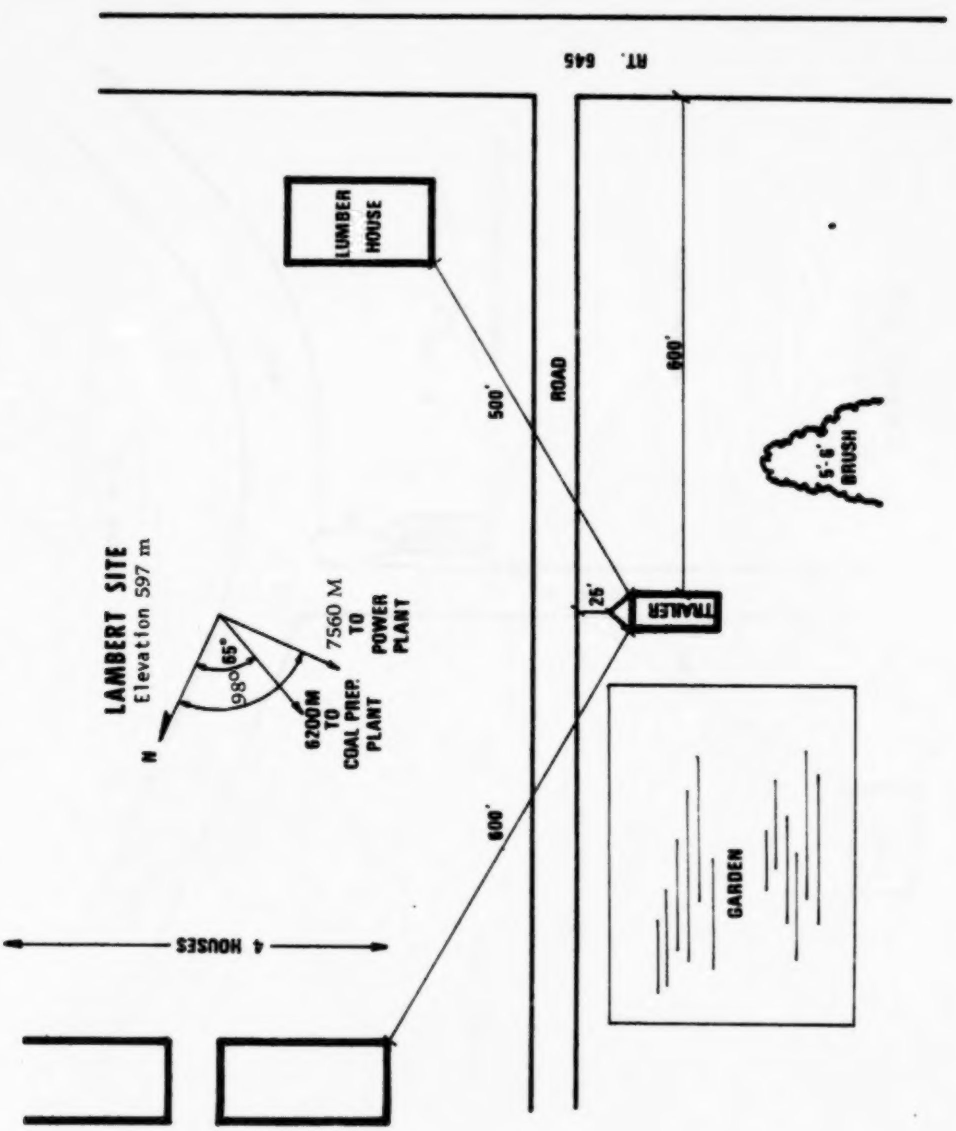
Elevation 792 m


HILL
BANNER HOUSE
300' FROM TRAILER
5 HOUSES
20' HIGH
15' STACK
N
11138 M TO COAL PREP. PLANT
8280 M TO POWER PLANT
58°
51°
CORN FIELD
105'
12' TREE
TRAILER
33'
48'
50' TREE
100'
60' TREE
CLINCH RIVER
BRIDGE
CASTLEWOOD

CASTLEWOOD SITE
Elevation 451 m


30 KM
TO
POWER PLANT
112°
N
CORN FIELD
HILL
TRAILER
20'
PASTURE
ROAD
HORSE & BARN
MOUNTAIN
KENT'S
RIDGE
SITE
Elevation 756 m


JOHNSON SITE
Elevation 719 m
CABBAGE FIELD
5750 M TO POWER PLANT
11°
N
HOUSE
300'
TRAILER
30'
5'
DRIVEWAY
ROAD
ROAD
TOBACCO FIELD
TOBACCO FIELD


LAMBERT SITE
Elevation 597 m
N
98°
65°
6200M TO COAL PREP. PLANT
7560 M TO POWER PLANT
LUMBER HOUSE
RT. 645
ROAD
500'
600'
25'
600'
TRAILER
BRUSH
5'-6'
GARDEN
4 HOUSES

APPENDIX B

MAJOR INSTRUMENT PERFORMANCE CHARACTERISTICS

MONITOR LABS MODEL 8450 SULFUR ANALYZER

The ML Model 8450 operates using the sulphur specific Flame Photometric Detection (FPD) measurement principle. The instrument measures the change in light intensity in a hydrogen flame burner chamber as sample air is introduced. The light intensity is measured and converted to a linear output that is proportional to the amount of sulfur compounds in the sample air. Since the 8450 responds to most all sulfur compounds, it was necessary to incorporate a Monitor Labs Model 8740 H_2S Scrubber to remove ambient H_2S from the sample air. The scrubber removes H_2S by heating the sample air to 130°C and passing it through a series of scrubber elements.

The manufacturer's stated specifications for the ML Model 8450 are as follows:

Ranges:	0-100 ppb, 0-1000 ppb
Maximum Noise:	1 ppb (peak-to-peak)
Minimum Detectable Concentration:	2 ppb (stated as 2 times maximum peak-to-peak)
Lag Time:	Less than 1 second
Precision:	1% full scale
Zero Drift:	± 2 ppb/day, ± 5 ppb/3 days
Span Drift:	± 5 ppb/day, ± 10 ppb/3 days for 0-1000 ppb range
Linearity:	± 1%
Sample Flowrate:	180 ml/min ± 10 ml/min
Time Constant:	Selectable 1, 5, 20, 60, 120 seconds
Maintenance Interval:	45 days
Unattended Operation:	7 days
Support Gas Required:	Hydrogen, 99.9% pure

The manufacturer's stated specifications for the ML Model 8740 are as follows:

Efficiency:	99% H_2S removal
Maximum SO_2 Depletion:	Less than 1%
Scrubber Element Life:	45,000 ppb H_2S-hours
Pressure Drop Thru 8740:	0.5" H_2O

The ML Model 8450 and Model 8740 combination performed well during the field program. Only one or two 8450 units occasionally exceeded the stated drift specifications, but no data loss was incurred as a result. Minor instrument malfunction and component failure did result in a small amount of lost data, but on the whole the 8450 units provided very stable operation. The 8450 minimum detectable concentration was effectively raised to between 5 and 8 ppb by the inclusion of the 8740 in the system. Field tests indicated that the H_2S Scrubber suppressed the SO_2 concentrations by about 3 or 4 ppb as compared to 8450 response without the scrubber in the system. Only one 8740 scrubber element failure was recorded during the field project.

MONITOR LABS MODEL 8440 NITROGEN OXIDES ANALYZER

The ML 8440 is a dual channel analyzer that simultaneously measured NO and NO_x using a chemiluminescence measurement system. NO_2 is then determined by simple subtraction of the NO signal from the NO_x signal.

In the 8440, the sample stream is split into two separate streams. One stream first passes through a molybdenum converter that converts all the NO_2 to NO, and then goes into the NO_x reaction chamber. The second stream passes directly into the NO reaction chamber after it passes through a length of teflon tubing that delays the sample stream the same length of time as the NO_x sample stream is delayed by the converter. This delay conserves the time integrity of the split sample streams. Each of the two reaction chambers are provided a supply of ozone from the 8440 ozone generation system. The reaction between the ozone and any NO that is in the sample stream produces light. The light intensity is then measured and electronically converted to a linear signal that is proportional to the amounts of NO in each reaction chamber. A temperature controlled critical orifice assembly accurately controls all the flows in the 8440 system.

The manufacturer's stated specifications for the ML Model 8440 are as follows:

Ranges:	0 to 200, 500, 1000, 2000, or 5000 ppb
Minimum Detectable Concentration:	2 ppb
Lag Time:	Less than 5 seconds
Zero Instability:	Less than 0.1% full scale per year
Span Instability:	Less than ± 1% full scale per day
Repeatability:	± 1% NO and NO_x, ± 1.4% NO_2
Sample Flowrate:	Less than 500 ml/min each channel nominal
Ozone Flowrate:	80 ml/min each channel nominal

In the field, the 8440 units were found to experience a large zero drift on the order of 10 or more ppb per week. Large span drifts also occurred somewhat regularly. The outputs of all the 8440 units contained varying amounts of noise that were independent of the magnitude of the output signal. The noise level in some of the instruments ranged as high as 10 or 15 ppb on the 0-2000 ppb range and a 20 second time constant. The minimum detectable concentration was, therefore, raised to not less than 10 ppb.

The large span and zero drifts in the 8440's did not result in any lost data due to the frequency of the multipoint calibrations performed on the instruments. Some data loss was incurred as a result of component failure in the 8440. The ozone generation system was a constant source of problems that resulted in data losses early in the project. A new ozone generating system developed by Monitor Labs relieved the failure problems of the earlier system.

MONITOR LABS MODEL 8410A OZONE ANALYZER

The ML Model 8410A measures ozone using the chemiluminescence principle. Sample air is introduced into a reaction chamber where it is combined with ethylene from an external source. Reaction between the ethylene and any ozone that is in the sample air produces light. The intensity of this light is measured, amplified, and converted to a linear output proportional to the ozone concentration in the sample air.

The manufacturer's stated specifications for the ML Model 8410A are as follows:

Ranges:	0 to 200, 500, 1000, 2000, or 5000 ppb
Minimum Detectable Concentration:	1 ppb
Lag Time:	Less than 3 seconds
Zero Instability:	Less than 0.1% full scale per year
Span Instability:	Less than ± 1% full scale per day
Repeatability:	± 1%
Sample Flowrate:	300 cc/min nominal
Ethylene Flowrate:	30 cc/min nominal
Support Gas Required:	Ethylene, CP grade

The ML Model 8410A provided reliable performance during the field program. Although not designed as a portable instrument, the 8410A stood up very well during its use in both the surface and airborne mobile sampling programs. Zero and span drifts were very small and the outputs contained little if any noise. A small amount of data loss was incurred as a result of infrequent minor component failure in the 8410A.

THETA SENSORS, INC. SERIES 7111 SO_2 MONITOR

The TSI Series 7111 SO_2 Monitor is a single-channel instrument that measures SO_2 concentrations through the use of a permselective membrane permitting selective redox reactions to occur within a sealed electrochemical transducer. The permselective membrane permits the passage of SO_2 into the transducer cell while inhibiting the passage of interfering gases. The transducer cell produces a signal that is directly proportional to the SO_2 concentration in the sample gas and is completely linear over the instrument range.

The manufacturer's stated specifications for the TSI Series 7111 SO_2 Monitor are as follows:

Range:	0 to 1000, 3000, or 10,000 ppb
Sensitivity:	1% of full scale
Accuracy:	± 2% of full scale
Repeatability:	± 1% of full scale
Zero Drift:	± 2% per day
Span Drift:	± 1% per day
Sample Flowrate:	0.6 standard cubic feet per hour
Response Time:	Less than 60 seconds
Temperature Compensation:	± 2% over any 10°F range
Temperature Range:	32°F to 113°F

Several problems were encountered with the TSI instrument in its use in the mobile sample program. Transducer failure was common and caused various drift problems that led to moderate loss of data. Although sometimes the instrument would perform as designed, it often became sensitive to the slightest motions encountered in the mobile sampling vehicles. This sensitivity resulted in full scale spikes, large zero and span drifts of 20 percent or more, and overall erratic performance. The TSI SO_2 monitor also experienced large negative zero and span drifts on the order of several percent of full scale per hour when the sample air became very cold and the instrument itself was kept within stated operating temperatures. Similar positive drifts occurred when the instrument was operated in ambient temperatures near 95°F even though this was within the stated operating range.

Not all drift problems resulted in loss of data since most of the drifts were linear with time and could be removed during data analysis. However, the spiking and erratic behavior associated with the motion sensitivity did result in moderate data losses.

MONITOR LABS MODEL 8500 CALIBRATOR

The ML Model 8500 used in the field program contained some or all of the following features:

- Zero Air production system
- NO dilution system
- NO_2 permeation system
- SO_2 permeation system
- Ozone generation system.

The Zero Air production system produces zero air from ambient air by first oxidizing all NO to NO_2 then scrubbing out all SO_2, NO_2, ozone, and other unwanted gases with an activated charcoal filter. The zero air thus produced is then available for use as zero or as dilution air for the NO, NO_2, SO_2, or ozone calibration gases.

The NO dilution system incorporates a cylinder of high concentration NO in dry nitrogen. The cylinder NO is introduced into the 8500 through a regulated flow capillary restrictor. This controlled NO flow is mixed with the dilution air to provide calibration level NO concentrations.

The SO_2 and NO_2 permeation tubes are contained in a temperature controlled oven that stabilizes the tubes' emission rates. Regulated dilution air is passed over the permeable membranes to provide SO_2 or NO_2 calibration gas to the respective analyzers.

Calibration level ozone concentrations are produced by the ultraviolet irradiation of zero air. The irradiation takes place in a temperature controlled oven that allows stable, controlled ozone production.

The SO_2, NO_2, and ozone systems were calibrated by Monitor Labs using the following methods:

SO_2:	Comparison to NBS SRM
NO_2:	Gas Phase Titration per the reference method
Ozone:	Bubbling into neutral buffered potassium iodide per the reference method.

All the dilution and zero air flows are controlled by precision 150 mm scale rotameters that were initially calibrated by Monitor Labs and routinely checked by GEOMET using NBS traceable mass flowmeters.

The manufacturer's stated specifications for the ML Model 8500 are as follows:

Accuracy
  ML Calibration of Sources: ± 5% relative to lab standards
  Flow Calibrations: ± 2% relative to lab standards
Dilution Air Source
  Total air flow available: 1000-8000 cc/min
  Total dilution flow/channel: 400-4000 cc/min
Oven Temperature Control: ± 0.1°C

One 8500 pump failure was recorded during the field project; however, no loss of analyzer data occurred as a result. The pressure regulating device in the NO dilution system was found to be in error from 10 to 50 percent in three of the 8500 units. As a result, the NO capillary flows had to be measured with a mass flowmeter to insure the generation of precise quantities of NO calibration gas. No data losses occurred as a result of the regulator errors since the analyzer calibration data could be reconstructed and corrected.

METEOROLOGY RESEARCH, INC. MODEL 1022 WIND SET

The MRI Model 1022 Wind Set consists of a cup anemometer, a wind vane, and a mounting crossarm. Also incorporated in the system is the MRI Model 1002 Transmuter.

The MRI cup anemometer works on the light chopper principle. A light chopper disc causes varying conductivity in a photocell as the anemometer cups rotate in the wind. The signal generated by the photocell is converted to a linear analog DC output by the Model 1002 Transmuter.

The MRI wind vane uses a dual potentiometer - wiper combination to give a 0° to 540° output that eliminates crossover problems at 360°. The potentiometer resistance is converted by the transmuter to a linear analog DC signal that is proportional to the wind direction. The transmuter also computes sigma azimuth values from the wind vane output.

The manufacturer's stated specifications for the MRI Model 1022 Wind Set are as follows:

Wind Speed
  Starting Threshold: 0.22 mps
  Response Distance: less than 1.5 meters for 63% recovery
  Flow Coefficient: 1.7 m/rev.

Accuracy: ± 0.06 mps or 1% of wind speed (whichever is greater)
Range: 0.22 mps to 54 mps maximum

540° Wind Direction
Starting Threshold: 0.31 mps
Distance Constant: 1.13 m
Damping Ratio: 0.4 at 10° angle of attack
Accuracy: ± 2.5°
Range: 0° to 540°
Phasing between Pot A and Pot B wipers: 0°

The MRI wind equipment performed well during the field program. Some bearing deterioration resulting in increased starting thresholds occurred in a few wind speed sensors. However, periodic lubrication and bearing replacement kept data losses to a minimum. Infrequent photocell failure was experienced, but again data losses were kept to a minimum with the help of spare wind speed sensors and spare photocell assemblies kept in the field.

The wind direction sensors performed remarkably well with only two or three potentiometer failures resulting in minimal data loss.

Most data losses that did occur with the MRI wind equipment were as a result of infrequent circuit board failure in the 1002 transmuter. Even these losses, however, were minimal because of the large number of spare circuit boards kept in the field.

METEOROLOGY RESEARCH, INC. MODEL 1053 VECTOR VANE

The MRI Model 1053 Vector Vane measures wind speed, horizontal wind direction (azimuth), and vertical wind direction (elevation). The MRI Model 1001 Transmuter was used with the Vector Vane in the Clinch River project.

Both the wind speed and azimuth measurement principles of the Vector Vane are the same as the MRI Model 1022 Wind Set. The Vector Vane uses a single potentiometer and wiper combination to measure elevation. The Model 1001 transmuter operates in the same manner as the Model 1002 but is larger and can accommodate up to 10 circuit cards.

The manufacturer's stated specifications for the MRI Model 1053 Vector Vane are as follows:

Wind Speed
  Starting Threshold: 0.33 mps
  Response Distance: 0.9 meters (63% recovery)
  Accuracy: ± 0.09 mps or 1% of wind speed (whichever is greater)
  Range: 0.33 mps to 50 mps maximum
Wind Direction and Elevation
  Starting Threshold: 0.33 mps
  Delay Distance: 0.9 meters (50% recovery)
  Damping Ratio: 0.5
  Azimuth Accuracy: ± 5.4° (1% of full scale)
  Elevation Accuracy: ± 2.4° (2% of full scale)
  Range
    Azimuth: 0° to 540°
    Elevation: -60° to +60°

The MRI Vector Vane and 1001 transmuter combination provided reliable field performance. No bearing failures were recorded, but two Vector Vane propellers required replacement after locally high winds damaged them. Data losses as a result of the damaged propellers and infrequent transmuter circuit board failures were minimal.

METEOROLOGY RESEARCH, INC. MODEL 815-1 TEMPERATURE SENSOR

The MRI Model 815-1 Temperature Sensor is a naturally aspirated system that is proportional to the ambient temperature when combined with the MRI Model 1002 Transmuter. The temperature sensor consists of a dual thermistor and resistor network to produce a linear resistance change with an ambient temperature change. The sensor housing is designed to shield the thermistor elements from both long- and short-wave radiation while allowing maximum transfer of heat.

The manufacturer's stated specifications for the MRI Model 815-1 Temperature Sensor are as follows:

Sensing Housing
  Effect of Radiation: 0.1°C with a wind speed of 1.5 mps or greater
  Air Flow: Naturally aspirated
Temperature Element
  Accuracy: ± 0.25°C
  Output: -15968 to +5835.5 ohms (variable)
  Range: -30°C to +50°C

No temperature sensor failures were recorded during the entire course of the field program. However, one or two transmuter circuit board failures did result in a very minimal amount of lost data.

METEOROLOGY RESEARCH, INC. MODEL 840 SERIES TEMPERATURE SENSORS

The MRI Model 840 Series Temperature Sensor is a shielded, power aspirated system that operated on the same principle as the MRI Model 815-1. Variations in the Model 840 series allowed the measurement of Δ temperature at two levels at the Tower site. Because of the number of circuit cards involved in this system, the Model 1001 Transmuter was used.

The manufacturer's stated specifications for the MRI Model 840 Series Temperature Sensor are as follows:

Sensor Housing	
Effect of Radiation:	Less than 0.05°C under maximum solar radiation conditions
Air Flow:	10 to 30 feet per second
Blower:	Continuous duty
Temperature Element	
Accuracy:	± 0.25°C
Output:	-15968 to 5835.5 ohms (variable)
Range:	-30°C to +50°C

No temperature sensor failures occurred during the field project; however, very minimal data losses occurred as a result of infrequent transmuter circuit board failure.

METEOROLOGY RESEARCH, INC. MODEL 840 SERIES RELATIVE HUMIDITY SENSOR

The MRI Model 840 Series Relative Humidity Sensor is a shielded, power aspirated system that produces resistance changes proportional to changes in ambient relative humidity. A pair of thermally matched strain gauges sense the stress in a system of cellulose crystalite structures comprised of organic and inorganic crystals. The hygro-mechanical stress of these crystals related to the moisture content of the air. The MRI Model 1001 Transmuter was used with the relative humidity system.

The manufacturer's stated specifications for the MRI Model 840 Series Relative Humidity Sensor are as follows:

Sensor Housing	
Air Flow:	10 to 30 feet per second
Blower:	Continuous duty
Humidity Element	
Accuracy:	± 3.0% RH
Range:	0% to 100% RH

The failure of the humidity element in the only sensor used in the field project resulted in considerable loss of data. An MRI spokesman stated that the elements generally deteriorated gradually so that a precise failure date would be hard to pinpoint. Because of apparent severe design problems, MRI discontinued production and marketing of the relative humidity sensor shortly after the start of the Clinch River project.

METEOROLOGY RESEARCH, INC. MODEL 370 RAIN GAGE

The MRI Model 370 Rain Gage contains an AC powered thermostatically controlled heater to convert snow and freezing rain to a measurable liquid state. A deep collecting funnel and a tipping bucket-reed switch combination provide the means for measuring precipitation. As the bucket is filled from the collecting funnel, it tips and closes the reed switch. Conversion from the number of switch closures to a DC signal proportional to precipitation amounts is performed by a circuit card in the MRI Model 1001 Transmuter.

The manufacturer's stated specifications for the MRI Model 370 Rain Gage are as follows:

Accuracy:	± 1% at 3 inch/hour rainfall rate
Bucket Capacity:	0.01" rain per tip
Reset Value:	1.00" (resets to 0.00")

No sensor or circuit board failures occurred during the field project. Periodic cleaning of the collector tube prevented any data losses due to plugging.

INTERNATIONAL LIGHT, INC. MODEL IL 200 UV-VISIBLE PHOTOMETER

The International Light, Inc. Model IL 200 UV-Visible Photometer measures light intensity with a vacuum photodiode tube. The spectral range measured is determined by the type of filters used on the optical input of the photodiode. (For the Clinch River project, response was limited to wavelengths between 355 and 390 nanometers.) The light intensity is measured in microamperes, but the instrument output is an analog DC voltage that is proportional to the light intensity.

The manufacturer's stated specifications for the ILI Model IL 200 UV-Visible Photometer are as follows:

Spectral Response:	355 to 390 nm
Sensitivity Factor:	1.445×10^{-5} (A) (cm^2) (W^{-1})
Ranges:	0 to 0.03, 0.1, 0.3, 1.0, 3.0, or 10.0 microamperes
Accuracy:	3% on all ranges
Linearity:	2% on all ranges

No sensor failures occurred during the field project.

MISCO 24-PORT SEQUENTIAL TOTAL PARTICULATE SAMPLER

The Misco 24-Port Sequential Total Particulate Sampler was specially designed for use in the Clinch River project by Misco Scientific. Each unit consisted of 24 sampling heads manifolded with electrically operated solenoids to one blower. A contact closure automatically started a 1-hour cycle on one sampling head, with a possible total of 24 hours of sampling utilizing all 24 heads. The units were equipped with a 24-hour circular recorder that indicated the flow for each sampling head.

ENVIRONMENTAL DATA CORPORATION DIRECT-VIEWING INDUSTRIAL GAS ANALYZER (DIGA)

The EDC DIGA-Series in-stack monitor operates on the principle of selective absorption of UV light by SO_2 and NO gas molecules. With a UV light source on one side of the flue gas duct and the sensor-receiver on the other side, the instrument gives an integrated value of the gas concentration across the path length.

The manufacturer's stated specifications for the EDC DIGA-Series are as follows:

Range
  NO: 0 to 1000 ppm
  SO_2: 0 to 1000 ppm
Accuracy: 2% of full scale
Repeatability: 1% of full scale
Response Time: 4 seconds

A few component failures resulted in some loss of data from the EDC monitor. Unreliable data were sometimes obtained when the flue gas opacity became very high (usually when the plant personnel were blowing out slag from the boilers).

APPENDIX C

DOCUMENTATION FOR CLINCH RIVER PLUME STUDY DATA TAPE

DATA OVERVIEW

Data collected, processed and archived during the Clinch River Plume Study in Complex Terrain covers the period from June, 1976 through September, 1977 and is presented in the six following data types.

1. Fixed Station Data

   This consists of hourly averaged aerometric data from each of the eight fixed monitoring stations linked via leased telephone lines to the ADAM (Aerometric Data Acquisition and Monitoring) recording system, running on a Data General Nova computer, installed at the Clinch River Power Plant site. There are eight fixed station data files, one for each site.

2. Mobile Ground Monitoring Data

   These data consist of aerometric measurements collected at different locations and times throughout the study period by two specially equipped mobile vans. The measurements supplement the Fixed Station data by providing measurements below the plume's ascertained direction of travel.

3. Airborne Monitoring Data

   These data were collected during two periods of intensive plume study, the first in November of 1976 and the second in July of 1977, using a helicopter equipped for aerometric sampling. The data were recorded approximately four to five times a second while making a series of plume traverses at different heights between two given ground based checkpoint locations. An approximate ground speed of 60 mph was maintained giving a sampling interval of approximately 20 ft. The reduced data gives a basis for investigating plume structure and behavior aloft by such techniques as construction of plume cross sections.

4. Sulfate Measurements

   Sulfate measurements were collected at six fixed stations and at some locations of the Mobile 1 van. The data were collected at selected times during the study.

5. Plant Operating Data

This consists of recorded hourly operating data for each of the three boiler units at the plant, collected in the plant control room together with monitored emissions of SO_2 and NO measured by a stack gas analyzer installed in the stack servicing boiler unit #3. Theoretical and estimated hourly emissions for all units are also included.

6. Upper Air Meteorological Data

This consists of pibal and T-sonde data giving wind directions and temperature aloft. The data were collected at regular times and intensified during periods of particular interest such as the helicopter sampling periods. The upper air data is augmented by ground level readings of wet and dry bulb temperatures and relative humidity taken at the pibal launch site just prior to releases.

Data Processing Information

The six different types of data are maintained in separate files on one 2400 foot magnetic tape. The tape is a 9-track nonlabelled ASCII tape recorded at 1600 bpi. The records are blocked but they do not span blocks. The original data files were produced on a PDP 11/70 IAS system. The data files as they appear on the tape are as follows:

File Number	File Description	Record Length	Block Size
1	Castlewood fixed-station data	176	3520
2	Hockey fixed-station data	176	3520
3	Johnson fixed-station data	176	3520
4	Lambert fixed-station data	176	3520
5	Kent's Ridge fixed-station data	176	3520
6	Nash's Ford fixed-station data	176	3520
7	Munsey fixed-station data	176	3520
8	Tower fixed-station data	176	3520
9	Sulfate data	176	3520
10	Upper-air meteorological data	44	3520
11	Mobile 1 - June 1976-August 1976	32	3520
12	Mobile 1 - September 1976-November 1976	76	3040
13	Mobile 1 - December 1976 - February 1977	76	3040
14	Mobile 1 - March 1977 - May 1977	76	3040
15	Mobile 1 - June 1977 - September 1977	76	3040
16	Mobile 1 - from strip charts for Julian days 222, 245, 246, 247, 251, 252, 257, 258, 260, 261, 264, 265, 266, 267, 268, 273, 302, 307, 308, of 1976 and days 199-204 of 1977	76	3040

File Number	File Description	Record Length	Block Size
17	Mobile 2 - from strip charts for Julian days 288, 363, 365 of 1976 and days days 4-7, 11-13, 25, 27, 31-35, 41, 45-48, 52-56, 59-62, 66-70, 74 of 1977	76	3040
18	Helicopter data for November 8, 9, 11, 13, 17, 1976	88	3520
19	Helicopter data for November 10, 1976 Events 9-36	88	3520
20	Helicopter data for July 20, 1977 Events 1-39	88	3520
21	Helicopter data for July 21, 1977 Events 41-45	88	3520
22	Helicopter data for July 23, 1977 Events 47-53	88	3520
23	Helicopter data for July 23, 1977 Events 416-428	88	3520
24	Helicopter data for July 23, 1977 Events 431-475	88	3520
25	Helicopter data for July 24, 1977 Events 501-543	88	3520
26	Helicopter data for July 24, 1977 Events 559-648	88	3520
27	Helicopter data for July 24, 1977 Events 652-662	88	3520
28	Helicopter data for July 26, 1977 Events 749-788, 797-803	88	3520
29	Helicopter data for July 27, 1977 Events 805-861	88	3520
30	Helicopter data for July 27, 1977 Events 866-914	88	3520
31	Helicopter data for July 27, 1977 Events 916-968	88	3520
32	Helicopter data for July 28, 1977 Events 994-077	88	3520
33	Helicopter data for July, 1977 Events 408-412, 545-557, 564, 610, 650, 701-747, 791-795, 970-992	88	3520
34	Plant operating data	76	3040

Fixed Station Data

The fixed station data are hourly averages maintained as separate files for each of eight stations. Accompanying the hourly average pollutant data are also the peak concentrations recorded during the hour ending at the given time. The station names are abbreviated to station codes six characters or less as TOWER, MUNSEY, NASHS, HOCKEY, CASTLE, KENTS, JOHNSN, and LAMBER. The table on the following pages describes the parameters and the formats contained on the fixed station hourly files.

Channel #	Variable Description	Column	Format*	Units	Missing**	Tower	Mursey	Nashs	Hockey	Castle	Kents	Johnsn	Lamber
	Station Code	1-6	A6	Code									
	Year	7-8	I2	Last Two Digits									
	Julian Day	9-11	I3	1-366									
	Hour of Day	12-13	I2	1-24									
	SO_2 Validity Flag	14-15	A2	Code									
1	Mean SO_2	16-20	F5.0	PPB by Volume	-999.	X	X	X	X	X	X	X	X
1A	Peak SO_2	21-25	F5.0	PPB by Volume	-999.	X	X	X	X	X	X	X	X
	NO_x Validity Flag	26-27	A2	Code									
2	Mean NO_x	28-32	F5.0	PPB by Volume	-999.	X	X	X	X	X	X		
2A	Peak NO_x	33-37	F5.0	PPB by Volume	-999.	X	X	X	X	X	X		
	NO_2 Validity Flag	38-39	A2	Code									
3	Mean NO_2	40-44	F5.0	PPB by Volume	-999.	X	X	X	X	X	X		
3A	Peak NO_2	45-49	F5.0	PPB by Volume	-999.	X	X	X	X	X	X		
	NO Validity Flag	50-51	A2	Code									
4	Mean NO	52-56	F5.0	PPB by Volume	-999.	X	X	X	X	X	X		
4A	Peak NO	57-61	F5.0	PPB by Volume	-999.	X	X	X	X	X	X		
	10 M Wind Speed Validity Flag	62-63	A2	Code									
5	10 M Wind Speed	64-68	F5.2	Meters per second	999.	X	X	X	X	X	X	X	X
	10 M Wind Direction Flag	69-70	A2	Code									
6	10 M Wind Direction	71-75	F5.1	Degrees	999.	X	X	X	X	X	X	X	X
	10 M Sigma Azimuth Flag	76-77	A2	Code									
7	10 M Sigma Azimuth***	78-82	F5.1	Degrees	999.	X	X	X	X	X	X	X	X
	10 M Temperature Validity Flag	83-84	A2	Code									
8	10 M Temperature****	85-89	F5.1	Degrees C	999.	X	X	X	X	X	X		
	UV Radiation Validity Flag	90-91	A2	Code									
9	UV Radiation	92-96	F5.2	Milliwatts per CM^2	999.	X							
	Relative Humidity Flag	97-98	A2	Code									
10	Relative Humidity	99-103	F5.0	Percent	999.	X							
	Precipitation Flag	104-105	A2	Code									
11	Precipitation	106-110	F5.2	Inches	999.	X							
	10 M Wind Elevation Angle Flag	111-112	A2	Code									
12	10 M Wind Elevation Angle	113-117	F5.0	Degrees	999.	X							

* All decimals implied

** A blank field indicates null channel

*** Sigma means the standard deviation of two minute scan values

**** Tower temperature at 4 m

Channel #	Variable Description	Column	Format*	Units	Missing**	Tower	Munsey	Nash	Hockey	Castle	Kents	Johnsn	Lamber
13	10 M Sigma Elevation Flag	118-119	A2	Code									
	10 M Sigma Elevation***	120-124	F5. 1	Degrees	999.	X							
14	Lower Temperature Difference Flag	125-126	A2	Code									
	0. 5 to 4 M Temperature Difference †	127-131	F5. 1	Degrees C	999.	X							
15	30 M Wind Speed Flag	132-133	A2	Code									
	30 M Wind Speed	134-138	F5. 2	Meters per Second	999.	X			X				
16	30 M Wind Direction Flag	139-140	A2	Code									
	30 M Wind Direction	141-145	F5. 1	Degrees	999.	X			X				
17	30 M Elevation Angle Flag	146-147	A2	Code									
	30 M Elevation Angle	148-152	F5. 0	Degrees	999.	X							
18	30 M Sigma Elevation Flag	153-154	A2	Code									
	30 M Sigma Elevation ***	155-159	F5. 1	Degrees	999.	X							
19	Upper Temperature Difference Flag	160-161	A2	Code									
	0. 5 to 30 M temperature Difference †	162-166	F5. 1	Degrees C	999.	X							
20	30 M Sigma Azimuth Flag	167-168	A2	Code									
	30 M Sigma Azimuth***	169-173	F5. 1	Degrees	999.	X							
	Filler Characters	174-176		Blank									

* All decimals implied

** A blank field indicates null channel

*** Sigma means the standard deviation of two minute scan values

† Difference is upper level minus lower level

The definitions of the data validity flags are as follows:

W - Measurement is based on less than 22 scan values within the hour.

M - NO_2 calibration gas used to adjust instrument was not properly controlled. Measurement shows changes relative to other measurements within a few days, but may not be quantitatively correct.

S - Derived from strip chart.

A - Arithmetic mean rather than vector mean of 2-minute scan values because wind speed or direction is missing.

L - Wind direction and speed is not reliable because wind speed is near or below the sensing threshold of the sensor.

E - Estimated zero applied to NO_x, NO data. Data is only qualitatively useful.

U - Data is uncalibrated (no zero/span applied). Data is only qualitatively useful.

C - Incorrect zero/span values have been applied to data. Data is only qualitatively useful.

N - NO_2 not computed since NO_x and NO are uncalibrated or calibrated incorrectly.

K - Kent's Ridge wind direction data unreliable.

The fixed station data files cover the following periods:

	Beginning			Ending		
	Year	Julian Day	Hour	Year	Julian Day	Hour
TOWER	76	153	10	77	273	24
HOCKEY	76	155	11	77	273	24
MUNSEY	76	153	10	77	273	24
NASHS	76	165	01	77	273	24
KENTS	76	258	15	77	273	24
CASTLE	76	176	14	77	273	24
JOHNSN	76	320	19	77	273	24
LAMBER	76	301	12	77	273	24

Sulfate Data

Sulfate measurements consist of data for sulfates collected on filters at six fixed stations, CASTLEWOOD, MUNSEY, HOCKEY, KENTS, NASHS and JOHNSON and at given locations of the MOBILE 1 van, abbreviated to two characters as CA, MU, HO, KE, NA, JO and MO respectively.

The net sulfate determined by analysis of the filters together with the volume of air that the filter was exposed to in the one-hour period starting at the given time was used in calculating a sulfate concentration. The record format is as follows:

Variable	Position	Format	Description
ST	1-2	A2	First 2 characters of station name. CA, MU, HO, KE, NA, JO, MO (Mobile 1)
DATE	3-8	I6	Date in Year (YY), Month (MM) and Day (DD) (i.e., YYMMDD)
TIME	9-12	I4	Time at start of sample in EST
FILTER #	13-16	I4	Filter number
$NETSO_4$	17-20	I4	Net sulfate (μg)
AIRFLOW	21-25	F5.1	Airflow (cubic meters)
SO_4CONC	26-30	F5.1	Sulfate concentration (μg/cu m)
	for MOBILE 1 (MO) location is also recorded (as follows):		
ELEV	31-34	I4	Elevation above sea level (ft)
DIST	35-38	F4.1	Distance from plant (km)
BEAR	39-42	I4	Bearing from plant (deg)
	43-44		Blank

Upper Air Meteorological Data

These data consist of vertical profiles of wind direction and speed, some with temperature, based on single- and double-theodolite pibal measurements, some with temperature-sondes. Ground level readings of wet and dry bulb temperatures and relative humidity taken with some of the releases are also included. Releases are identified by Gregorian date and time in EST.

At each height there may be wind speed and wind direction or temperature or all three. Minute refers to the elapsed time in minutes since the pibal/t-sonde release and is used to interpolate heights to map significant temperature structures as well as to compute wind speeds and wind directions.

The wind speed and direction are actually averages over the layer extending from the height one minute earlier to the height at which they are recorded. Therefore, the speed and direction should be considered applicable to a height midway between the height one minute earlier and the height at which they are recorded.

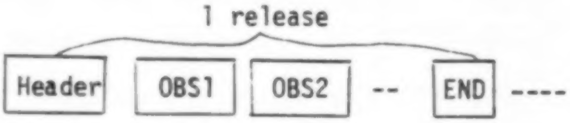
Example:

Minute	Height	Wind Speed	Wind Direction	Temperature
0.0	0	Missing	Missing	5.7
1.0	160	2	275	5.0
2.0	320	4	292	3.8

In the above example the wind speed of 2 m/sec and direction of 275° should be applicable to a height of 80 m and the wind speed of 4 m/sec and direction of 292° should apply to 240 m. The temperatures, however, apply to the heights given on the records.

Data relating to a single release is recorded on the file in records of three types as follows:

1. HEADER 2. OBSERVATION 3. END



The format of each of the three different types of records within a release follows.

1. HEADER RECORD

This is always the first record of each sounding and contains data relating to the release as a whole. The record format is:

Variable	Position	Format	Description
DATE	1-6	I6	Gregorian date in YYMMDD form (i.e., YY = Year, MM = Month, DD = Day)
TIME	7-10	I4	Time of release in EST in form of HHMM (i.e., HH = Hour, MM = Minute)
TYPE	11-11	I1	A "1" identifies this record as a header record
BASE	12-13	A2	Baseline
HUMIDITY	14-16	I3	Relative humidity (%)
DRYBULB	17-21	F5.1	Dry bulb temp (°C)
WETBULB	22-26	F5.1	Wet bulb temp (°C)
	27-32		Blank

Baselines are AB, BC, AC for double theodolite reductions and SA, SB for single theodolite releases from release points A and B respectively. Before October 19, 1976, releases were also made using a baseline near the Tower site. These are designated as baseline TW. Single theodolite soundings from the Tower site can be identified by the constant rate of rise of the balloon after the second minute.

2. OBSERVATION RECORD

This record contains data for the heights within the sounding designated by the previous HEADER record. Data are given successively by increasing height.

The record format is:

Variable	Position	Format	Description
DATE	1-6	I6	Gregorian date in YYMMDD form
TIME	7-10	I4	Time of release in EST
TYPE	11-11	I1	A "2" identifies this record as an observation record
MINUTE	12-15	F4.1	Minutes since release
HEIGHT	16-19	I4	Height of observation (meters) (see example, p. 152)
SPEED	20-22	I3	Wind speed for layer from this height to previous height (m/sec)
DIRECTION	23-25	I3	Wind direction for layer from this height to previous height (degrees)
TEMP	26-30	F5.1	Temperature at this height (°C)
	31-32		Blanks

Missing values are as follows:

SPEED	-99
DIRECTION	-99
TEMP	-99.9

3. END RECORD

This record indicates the end of a release and is followed by another HEADER record or an end of file. The record format is:

Variable	Position	Format	Description
DATE	1-6	I6	Gregorian date in YYMMDD form
TIME	7-10	I4	Time of release in EST
TYPE	11-11	I1	A "3" identifies this record as an END record
	12-32		Blank

Ground Mobile Monitoring Data

The ground mobile monitoring data taken during the Clinch River field study are contained in files 11 through 17 of the tape.

Ground mobile monitoring data consists of data collected at different locations by the two mobile ground monitoring vans, designated Mobile 1 and Mobile 2. The majority of the data was originally recorded every 30 seconds on cassettes in the mobile units and then transcribed to 9 track ASCII reels. Each location sampled was identified by an event marker and time which were also recorded on the cassette. The azimuth, distance and elevation of each location sampled was then abstracted from the operating log and merged with the data on tape using the time and event flag to match records. The data were also recorded on strip charts, and for the periods when the cassette recorders were not operating, the data was transcribed from the strip charts, keypunched and processed into files of the same format as the tape data. The data from strip charts is in the form of average and peak pollutant concentrations for each event, contained on separate, consecutive records.

Data recorded were SO_2 for Mobile 2 and SO_2, NO_x, NO_2, NO, O_3, wind speed, wind direction and temperature for Mobile 1. Each channel's data were converted to engineering units using the appropriate scale for each channel and zero span calibrations applied using values taken before each run. The calibrated data was recorded on a file in the following format.

Variable	Position	Format	Description
UNIT	2-2	I1	Mobile unit # (1 or 2)
YEAR	4-5	I2	Last 2 digits of year (76 or 77)
JDAY	6-8	I3	Julian day
TIME	10-13	I4	Time of scan (Eastern Standard Time)
SEC	14-15	I2	Second of scan
FLAG	16-16	A1	A or P (indicating average or peak for the event)
EVENT	17-19	I3	Event marker
EASTING	20-27	F8.2	Easting distance from plant (decameters)
NORTHING	28-35	F8.2	Northing distance from plant (decameters)
ELEV	36-40	I5	Elevation (ft above sea level) at the start of event
SO_2	44-47	I4	SO_2 concentration (ppb)
NO_x	48-51	I4	NO_x concentration (ppb)
NO_2	52-55	I4	NO_2 concentration (ppb)
NO	56-59	I4	NO concentration (ppb)
O_3	60-63	I4	O_3 concentration (ppb)
WS	64-67	I4	Wind speed (mph)
WD	68-71	I4	Wind direction (degrees)
TEMP	72-75	I4	Temperature (°C)
	76		Blank

Missing value indicators of -999 are used for all pollutants and meteorological data, except calm winds are indicated by WS=0 and WD=90.

Airborne Monitoring Data

Measurements of the plume taken by instrumentation aboard a helicopter during two sampling periods (November 1976 and July 1977) are contained in files 18 through 33 on the tape.

Helicopter data from the two airborne monitoring periods were recorded approximately 4 to 5 times per second on cassette tape while making a series of plume traverses at different heights between two given ground based checkpoint locations. A ground speed of approximately 60 mph was maintained giving a sampling interval of approximately 20 ft. The pollutant data were also recorded on stip charts. For periods during which the cassette recorder was not operating the strip chart data were transcribed, keypunched and processed into files of the same format as the tape data. The significant points (maxima and minima) of the chart trace were coded for each helicopter traverse. Since the maxima and minima occurred at slightly different times for each pollutant, each record was filled in with values for all pollutants by linearly interpolating over time between the successive maxima and minima. The calibrated data was recorded on a file in the following format:

Variable	Position	Format	Description
UNIT	2-2	I1	Mobile unit # (3)
YEAR	4-5	I2	Last 2 digits of year (76 or 77)
JDAY	6-8	I3	Julian day
TIME	10-13	I4	Time of scan (Eastern Standard Time)
SEC	14-15	I2	Second of scan
EVENT	17-19	A3	Event marker
EASTING	20-27	F8.2	Easting distance from plant (decameters)
NORTHING	28-35	F8.2	Northing distance from plant (decameters)
ELEV	36-40	I5	Elevation (ft above sea level) of helicopter
SO_2	44-47	I4	SO_2 concentration (ppb)
NO_x	48-51	I4	NO_x concentration (ppb)
NO_2	52-55	I4	NO_2 concentration (ppb)
NO	56-59	I4	NO concentration (ppb)
O_3	60-63	I4	O_3 concentration (ppb)
RH	64-67	I4	Relative humidity (%)
	68-83		Blank
TEMP	84-87	I4	Temperature (°C)
	88		Blank

All event markers are designated by numbers except on November 8, 1976, some events are designated by numbers and the letter "A". Missing value indicators of -999 are used for the pollutants and relative humidity data. Any negative number can be considered missing for the temperature data.

Records containing "333" in the event field are used to separate traverses on files 18-32. The airborne monitoring data in these files are uncorrected for instrument response time and the time lag involved in the gas reaching the instruments from the base of the helicopter. These adjustments are considered in the data analysis phase of the project.

Plant Operating Data

The plant operating data for the coal-fired Clinch River Power Plant is contained in one file on the tape. This data covers the period June 1, 1976 through September 30, 1977. The data consists of weekly average coal heat content and heat rate for each of the three units, a daily coal sulfur content (actually a 7-d running average of sulfur content of coal deliveries to the plant), and hourly SO_2 and NO emission rates, stack temperatures, exhaust airflow rates, and generator loads for each unit. Also included are hourly plant control room readings of barometric pressure. The SO_2 and NO emissions data consist of monitored emission rates for Unit #3 for a significant portion of the study, along with emissions for all three units calculated by two separate methods. Emission estimates were made using EPA emission factors (labelled "theoretical") and also through the use of regression equations (labelled "estimated") derived from hour by hour comparisons of generator load, sulfur content and measured emissions for Unit #3.

The file is structured as follows. The data for one day is contained in 25 consecutive records. The first record which is the daily header record contains the date, sulfur content, heat content and heat rate. This is followed by 24 hourly records, each containing emission rates, stack temperatures, exhaust airflow rates, and generator loads. The file format is presented on the following page. Missing value indicators of 999 are used for all the hourly plant data.

Fourteen days of suspicious SO_2 monitoring data exist on the plant data file. Fifty-one days of NO monitoring data are also suspicious. These data are qualitatively useful despite the stack monitor being out of calibration. The dates of the suspicious data are contained in Section 5.

PLANT OPERATING CHARACTERISTIC RECORD FORMAT FOR MAGNETIC TAPE

	Record Position	Character Format	
Daily Header Record:			
Year	1-2	I2	76 or 77
Month of Year	3-4	I2	1 to 12
Day of Month	5-6	I2	1 to 31
Sulfur Content of Fuel	7-10	F4. 2	Percent
Fuel Heat Content, Unit #1	11-15	I5	BTU per pound
Heat Rate, Unit #1	16-20	I5	BTU per kilowatt-hour
Fuel Heat Content, Unit #2	21-25	I5	BTU per pound
Heat Rate, Unit #2	26-30	I5	BTU per kilowatt-hour
Fuel Heat Content, Unit #3	31-35	I5	BTU per pound
Heat Rate, Unit #3	36-40	I5	BTU per kilowatt-hour
	41-76		Blank
Hourly Records			
Stack Temperature, Unit #1	1-3	I3	Degrees Kelvin
Air Exhaust Rate, Unit #1	4-6	I3	Cubic meters per second
Net Generator Load, Unit #1	7-9	I3	Megawatts
Theoretical SO_2 Emission Rate, #1	10-12	I3	Grams per second
Estimated SO_2 Emission Rate, #1	13-15	I3	Grams per second
Theoretical NO Emission Rate, #1	16-18	I3	Grams per second
Estimated NO Emission Rate, #1	19-21	I3	Grams per second
Stack Temperature, Unit #2	22-24	I3	Degrees Kelvin
Air Exhaust Rate, Unit #2	25-27	I3	Cubic meters per second
Net Generator Load, Unit #2	28-30	I3	Megawatts
Theoretical SO_2 Emission Rate, #2	31-33	I3	Grams per second
Estimated SO_2 Emission Rate, #2	34-36	I3	Grams per second
Theoretical NO Emission Rate, #2	37-39	I3	Grams per second
Estimated NO Emission Rate, #2	40-42	I3	Grams per second
Stack Temperature, Unit #3	43-45	I3	Degrees Kelvin
Air Exhaust Rate, Unit #3	46-48	I3	Cubic meters per second
Net Generator Load, Unit #3	49-51	I3	Megawatts
Theoretical SO_2 Emission Rate, #3	52-54	I3	Grams per second
Measured SO_2 Emission Rate, #3	55-57	I3	Grams per second
Estimated SO_2 Emission Rate, #3	58-60	I3	Grams per second
Theoretical NO Emission Rate, #3	61-63	I3	Grams per second
Measured NO Emission Rate, #3	64-66	I3	Grams per second
Estimated NO Emission Rate, #3	67-69	I3	Grams per second
Barometric Pressure at Plant	70-74	F5. 2	In. of mercury
	75-76		Blank